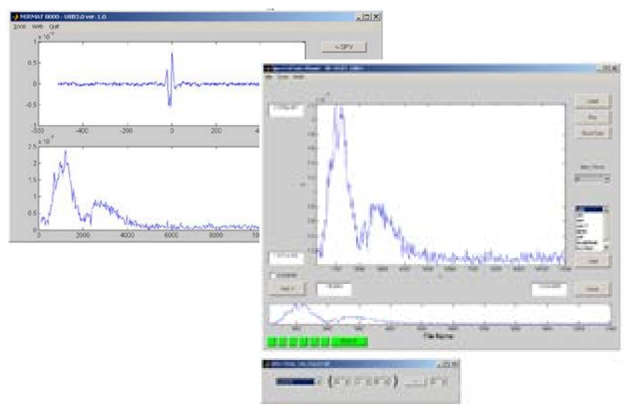
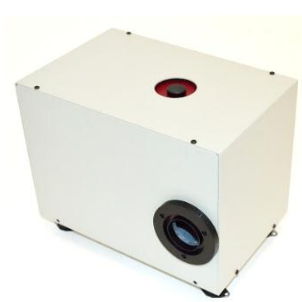
MIR8035™ SP01 Series

Oriel® Modular FT-IR Spectrometers and Related Products





User's Manual

ORIEL® INSTRUMENTS
A Newport Corporation Brand

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1 GENERAL INFORMATION

Thank you for your purchase of this FT-IR system from Oriel Instruments.

Please carefully read the following important safety precautions prior to unpacking and operating this equipment. In addition, please refer to the complete User's Manual for additional important notes and cautionary statements regarding the use and operation of the system.

Do not attempt to operate the system without reading all the information provided with each of the components.

1.1 SYMBOLS AND DEFINITIONS

	WARNING Situation has the potential to cause bodily harm or death.
	CAUTION Situation has the potential to cause damage to property or equipment.
	ELECTRICAL SHOCK Hazard arising from dangerous voltage. Any mishandling could result in irreparable damage to the equipment, and personal injury or death.
	EUROPEAN UNION CE MARK The presence of the CE Mark on Newport Corporation equipment means that it has been designed, tested and certified as complying with all applicable European Union (CE) regulations and recommendations.
Note:	Additional important information the user or operator should consider.

Please read all instructions that were provided prior to operation of the system.

If there are any questions, please contact Oriel Instruments or the representative through whom the system was purchased.

1.2 GENERAL WARNINGS

- Read all warnings and operating instructions for this system prior to setup and use.
- Do not use this equipment in or near water.
- To prevent damage to the equipment, read the instructions in the equipment manual for proper input voltage.
- This equipment is grounded through the grounding conductor of the power cords.
- Route power cords and other cables so they are not likely to be damaged.
- Disconnect power before cleaning the equipment
- Do not use liquid or aerosol cleaners; use only a damp lint-free cloth.
- Lock out all electrical power sources before servicing the equipment.
- To avoid explosion, do not operate this equipment in an explosive atmosphere.
- Qualified service personnel should perform safety checks after any service.
- If this equipment is used in a manner not specified in this manual, the protection provided by this equipment may be impaired.
- To prevent damage to equipment when replacing fuses, locate and correct the problem that caused the fuse to blow before re-applying power.
- Do not block ventilation openings.
- Do not position this product in such a manner that would make it difficult to disconnect the power cords.
- Use only the specified replacement parts.
- Follow precautions for static sensitive devices when handling this equipment.
- This product should only be powered as described in the manual.
- Do not remove the cover for normal usage

1.3 ELECTRICAL HAZARDS

Make all connections to or from the power supply with the power off.

Do not use the power supply without its cover in place. Lethal voltages are present inside.

1.4 FIRE HAZARDS

Light sources are extremely hot during operation, and remain hot for several minutes after being shut off. Keep flammable objects away from the IR source and its emitter or lamp.

To avoid fire hazard, use only the specified fuses with the correct type number, voltage and current ratings as referenced in the appropriate locations in the service instructions or on the equipment. Only qualified service personnel should replace fuses.

1.5 LAMP HANDLING

Never touch any lamp or the reflector's inner surface with bare fingers or other contaminates. Skin oil or other substances can burn into the lamp envelope during operation and negatively affect the lamp's performance and lifetime.

Always wear appropriate gloves when handling any lamp. Avoid any mechanical strain during handling. Do not operate the lamp without all housing panels in place.

Lamps become very hot after only a few minutes of operation (up to 150°C) and remain quite hot for at least 10 to 15 minutes after being turned off.

1.6 LASER HAZARDS

The FT-IR scanner contains a Class IIIA laser. The fully assembled FT-IR system functions as a protective housing for the laser. A safety interlock prevents the laser from operating with the cover off. Eye protection is required if operating this laser in such a manner as to be exposed to the beam or its reflection. It is strongly suggested that personnel who operate this instrument understand and utilize laser safety practices appropriate for a Class IIIA laser. The scanner should never be set up in such a manner that unprotected bystanders may be exposed to the laser's output beam.

2 INTRODUCTION

The MIR8035™ has been designed to be useful for routine analytical applications for an FT-IR as well as non-traditional applications where modular design is required for flexibility in the optical path. The MIR8035 was designed specifically for Researchers and OEMs who want an instrument easily adaptable to their special needs, at an economical price, and without compromise in performance. The MIR8035 has selectable resolution starting with 0.5 cm^{-1} and a very broad spectral range depending on choices of sources, optics, detectors and beam splitters. The MIR8035 is commanded by MIRMat™, a software package that provides sophistication for routine analysis that allows you to write custom routines to control the system. This package is also compatible with Active X.

Oriel utilized a modular approach when designing the MIR8035. We made the components that restrict the use of FT-IR instruments (sources, detectors and sample compartments) interchangeable, so you do not have to break it apart when your needs change – simply switch out the component(s).

Figure 1 illustrates how the MIR8035 works. Very simply, the scanner modulates the radiation from the source or sample; the electronics board (in the scanner) digitizes the analog signals from the detection system and sends them to a computer through a USB 2.0 interface. MIRMat software is used for instrument control and data handling.

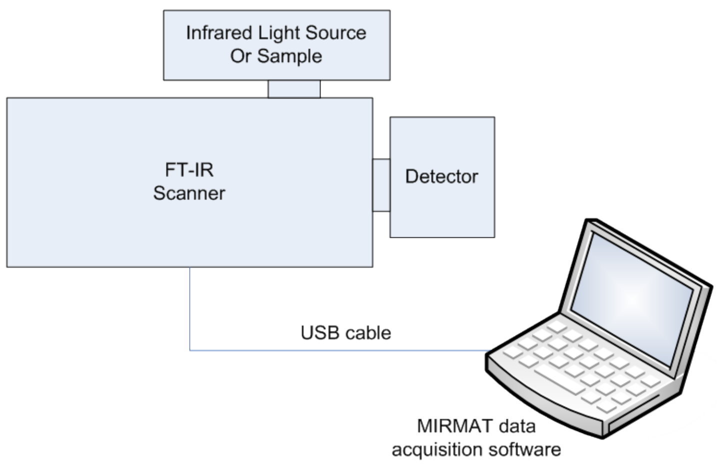

Figure 1: Basic System Diagram

A complete MIR8035 FT-IR Spectrometer system is composed of:

- MIR8035 scanner with beam splitter and windows installed
- IR Source or sample
- IR Detector
- MIRMat software

The flexibility of the modular MIR8035 FT-IR Spectrometer allows you to choose either an Oriel or your own Source and Detector to complete your FT-IR system. The flowchart in Figure 2 provides a quick reference to which detectors and sources are offered by Oriel Instruments. For questions, please contact an Oriel Technical Sales Engineer.

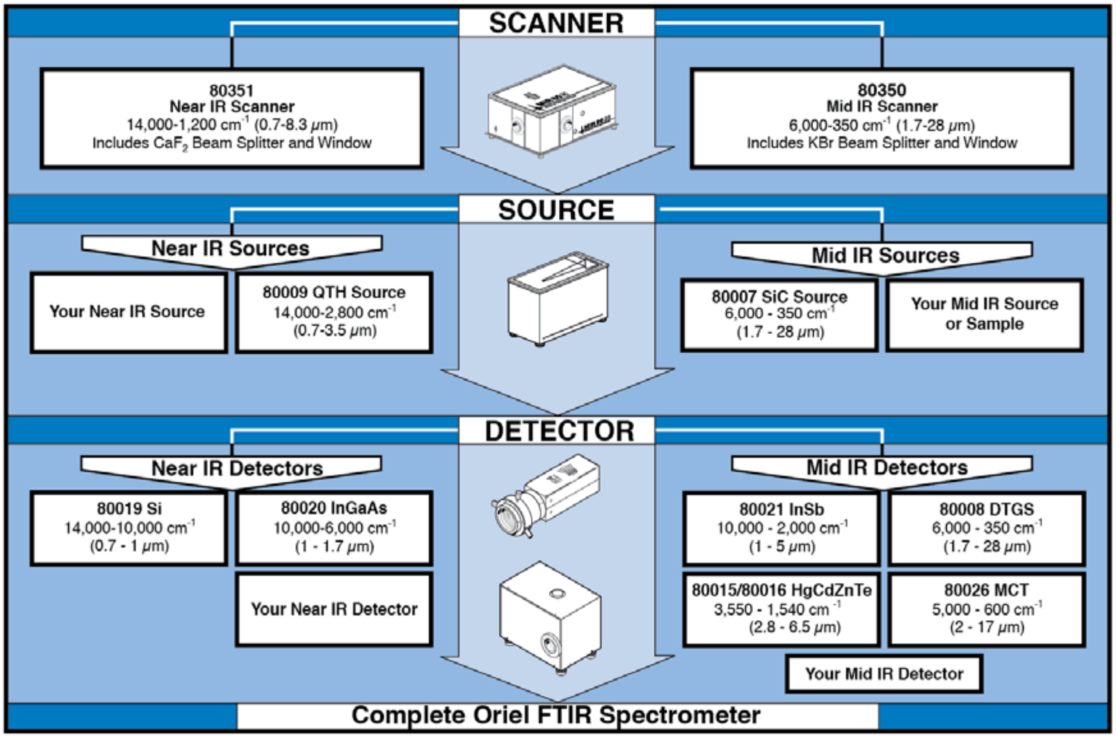

Figure 2: Building a Complete System

The MIR8035 uses a scanning Michelson Interferometer. Our optical layout, as shown in Figure 3, includes corner cubes and a retro-reflector. The unique layout is immune to tilt and shift. The retro-reflector and beam splitter are mounted together, providing accurate alignment while desensitizing the system to vibrations and temperature variations. This “unibody” approach to the beam splitter makes for easy interchangeability with a minimum of realignment required.

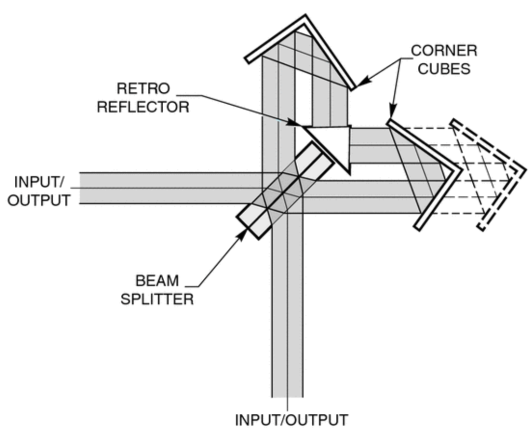

Figure 3: Optical Layout

3 SYSTEM SETUP

3.1 WHAT'S INCLUDED WITH THE SHIPMENT

Items provided with all FT-IR system orders:

- Model 80350 or 80351 Scanner with beam splitter and windows
- MIRMat software installation CD
- MIR MIR8035 ActiveX / Drivers CD
- USB 2.0 cable
- 3/32 hex wrench
- Alignment kit (includes reticle, hex wrench, laser safety glasses, instructional video)

Optional items:

- IR Source (typically ordered and shipped with scanner)
- IR Detector (typically ordered and shipped with scanner)
- Accessory Compartment
- Fiber Coupler Assembly
- Fiber Coupler Adapter(s)
- IR Fiber Optic Cables
- Off-Axis Parabolic Reflectors

3.2 ADDITIONAL ITEMS REQUIRED

The operator shall have the following items on hand in order to proceed with setting up the scanner and configuring the system. Note that the MIR8035 system requires the use of MIRMat software in order to complete the system setup. The individual installing the software and drivers is required to log onto the computer using Administrator privileges. The following items are required:

- Flat blade and philips screwdrivers
- Computer with the following:
  - ✓ Microsoft Windows XP service pack 2 or greater or Windows 7 (32 bit) operating system
  - ✓ 500 MB minimum free hard drive space
  - ✓ 2 GHz processor
  - ✓ 512 MB RAM
  - ✓ USB 2.0 port
  - ✓ CD-ROM Drive

3.3 INSTRUMENT LOCATION

Choose an installation location where the electrical requirements can be met for the system and the environment is suitable for the materials contained in the system.

The scanner contains extremely hygroscopic materials, such as potassium bromide (KBr). The scanner, source and detector also contain delicate gold-coated optical parts. Therefore, the instrument must operate or be stored in a controlled laboratory environment where relative humidity does not exceed 30%.

The shipping container and scanner contain desiccant, allowing the system to be transported without any negative effects due to humidity. It is the user's responsibility to ensure that the system is operated or stored in a low humidity environment.

Note that damage caused by mishandling or placement in an inappropriate environment is not covered under warranty.

3.4 UNPACKING

The system is carefully packaged to minimize the possibility of damage during shipment. Follow these steps to unpack the FT-IR system safely:

1. Inspect the shipping crate for external signs of damage or mishandling.
2. Place the unopened box in the lab/work area where you will be using the MIR MIR8035 and wait 24 hours before unpacking the instrument to let it achieve equilibrium with ambient conditions.
3. After 24 hours, take the instrument out of the box.
4. Wait 1 hour before opening the sealed plastic bag containing the Scanner.
5. Put on latex gloves. Remove the Scanner from its bag.
6. Remove the desiccant, place it in the plastic bag, and seal it with a twist tie.
7. Remove all other items from the shipping container.
8. Inspect the contents to ensure that nothing is missing or damaged before proceeding with setting up the system. Ensure that power cords are provided for all are instruments, and they are the appropriate type for the locale.

It is extremely important to save the crate, plastic bags and desiccant provided with the system.

These items are required for appropriate storage and safe transportation of the system.

3.5 SETTING UP THE SYSTEM

Place the scanner in its final location for operation. Connect the source and detector to the scanner. Remove the screws along the perimeter of the cover of the FT-IR scanner using a philips head screwdriver in order to remove the cover.

The scanning mechanism is locked for transportation purposes.
Never operate the instrument without unlocking the scanning mechanism.
Failure to remove the locking screw will result in catastrophic failure.

The locking screw for the scanning mechanism is shown in Figure 4. Unscrew and remove the locking screw using a philips head screwdriver. Manually check to ensure mechanism can move freely.

Never slide, tilt or move the scanner after the mechanism has been unlocked. Keep the locking screw is a safe location for moving the instrument in the future.

Place the cover back onto the scanner and secure with the screws provided. It is important to note that the cover must be on the instrument and held in place using all cover screws during operation. This satisfies the safety interlock mechanism, ensures stable data and minimizes the number of random particulates able to enter the instrument cavity.

Plug the Oriel detector cable into the connector on the side of the scanner. If the detector is not from Oriel, refer to Section 0 for connector pinouts. Add liquid nitrogen to the detector, if required.

Connect the USB cable to the scanner, but do not connector the cable to the computer until instructed to do so by this user's manual.

Connect all power cords to the instruments, and then plug them to the electrical mains.

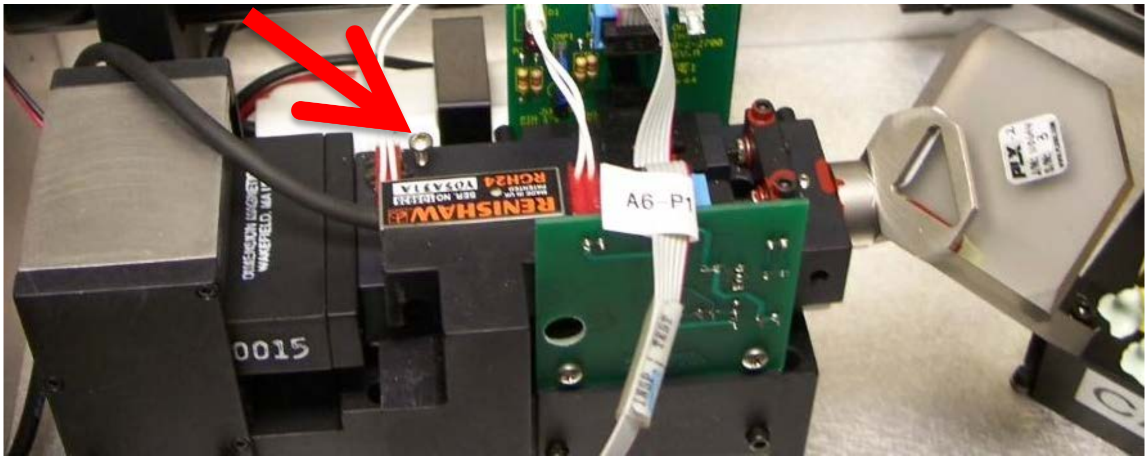

Figure 4: Unlocking Moving Mechanism

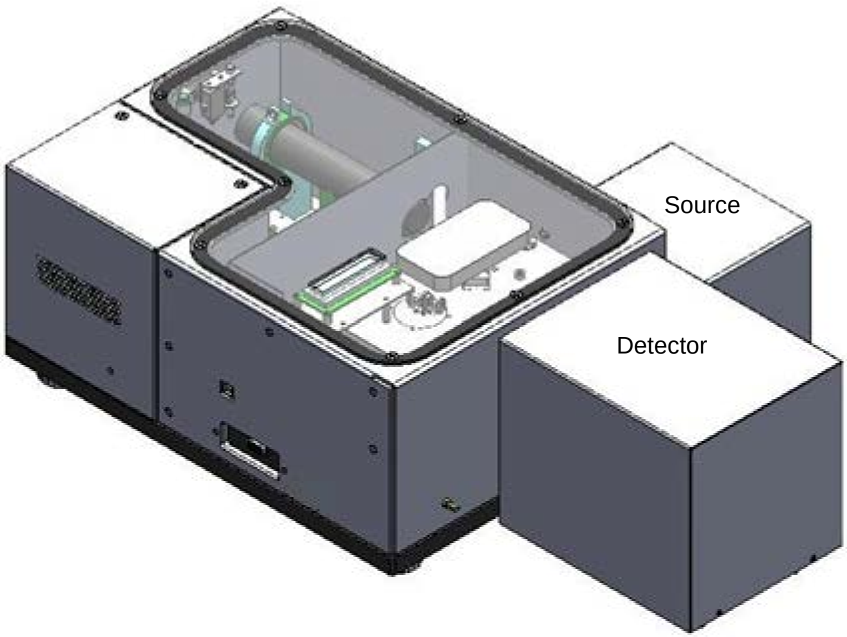

Figure 5: Scanner with Source and Detector

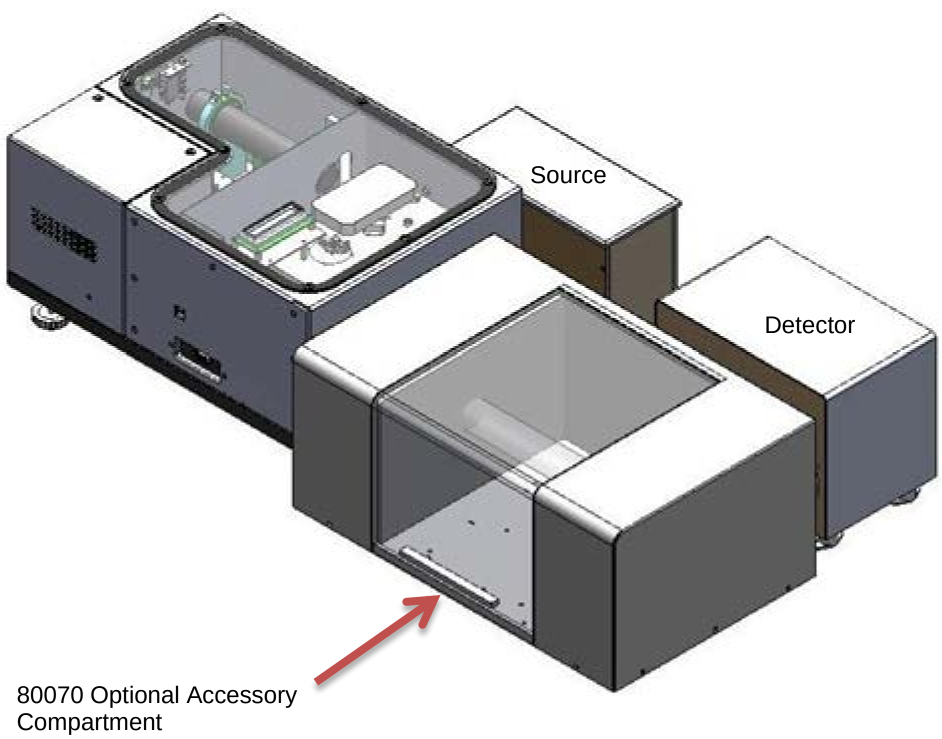

Figure 6: Complete System with Accessory Compartment

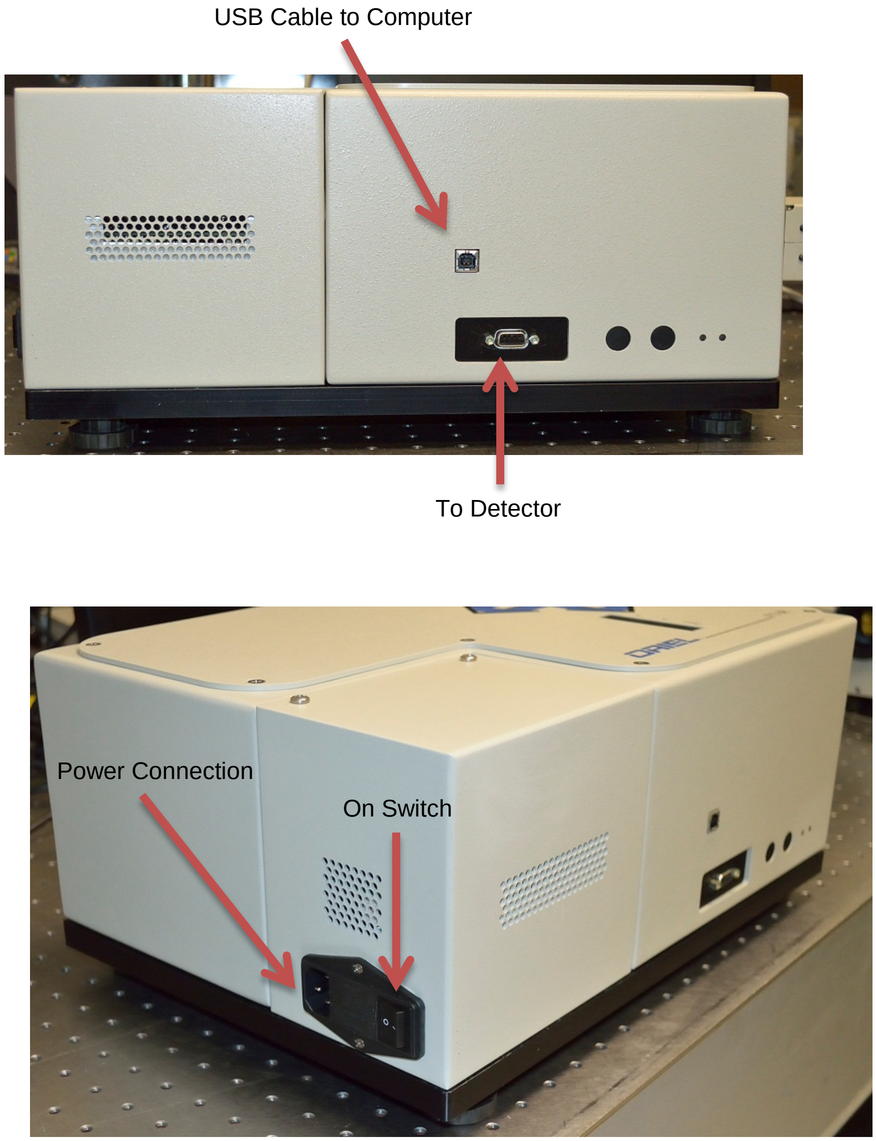

Figure 7: Scanner Connectors

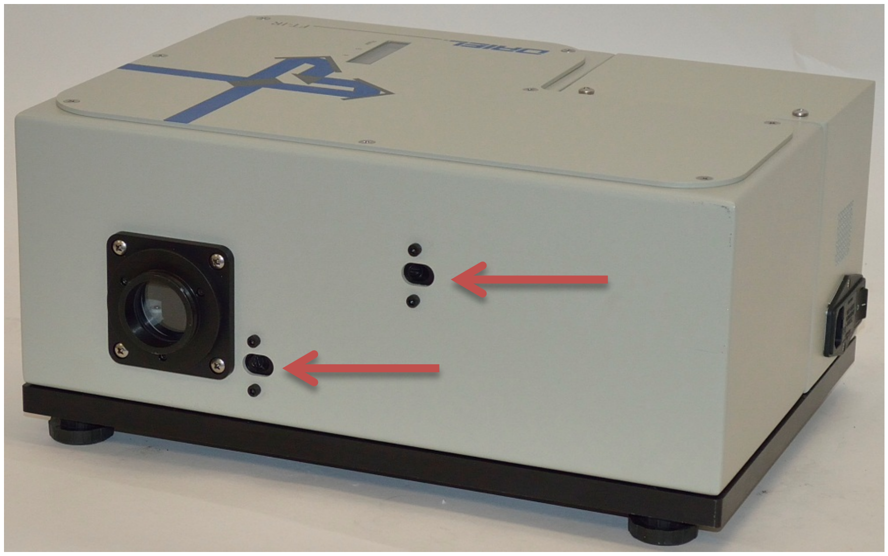

Figure 8: Beamsplitter Alignment Access Points

3.6 FIRST TIME STARTUP

Ensure that the scanning mechanism was unlocked prior to powering up the instrument. If unsure, remove the cover and check before proceeding. Then apply power to all instruments in the system.

Before turning on the scanner, the scanning mechanism must be unlocked.

A liquid crystal display (LCD) is located on the top of the scanner, as shown in Figure 9. “A” and “B” indicate the two signal levels after the beam splitter. The phase is between the two signals is also displayed. **The system must warm up for at least 30 minutes** to stabilize the scanner’s internal temperature in order to obtain accurate readings.

If both signal readings are greater than 25% and the phase is from 88° to 92°, refer to Section 4 for the MIRMat software installation procedure. Ideally, the percentages will be at 50%, with a maximum of 5% difference between the two readings.

If the signals being displayed are less than 30%, the beam splitter requires realignment. Refer to Section 7.1 for more information. Once the beam splitter alignment is complete, re-check the LCD readings. If they are acceptable, continue to Section 4 to install the MIRMat software.

If the phase being displayed is not within the acceptable range as noted above, the phase requires adjustment. Refer to Section 14.2 for more information. Once the phase reading is correct, re-check the signal readings on the LCD. If all readings are acceptable, continue to Section 4 to install the MIRMat software.

Turn off the FT-IR scanner until prompted to turn it on during the driver installation process, as noted in Section 6.2.

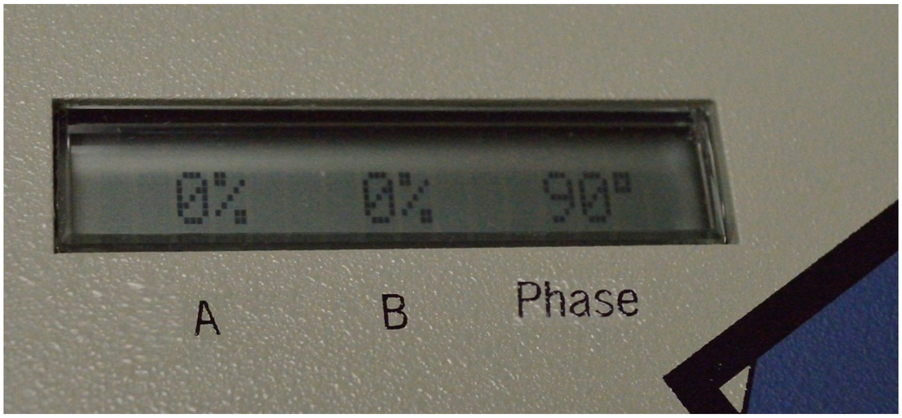

Figure 9: LCD Display

4 ACTIVE X INSTALLATION

4.1 COMPUTER PRIVILEGES

The individual performing the installation must have administrator privileges for the computer. Refer to Section 3.2 for the minimum system requirements. When installing onto a Windows 7 computer, the installation must be run in compatibility mode for Windows XP Service Pack 3.

4.2 ACTIVE X INSTALLATION PROCEDURE

This section will guide the user through the installation process. Please note that the Figures shown are based upon an installation performed on a computer with a Windows 7 32-bit operating system. Do not connect the USB cable to the computer until directed to do so.

1. Insert the Active X CD into the computer's CD-ROM drive. Open the contents of the CD.

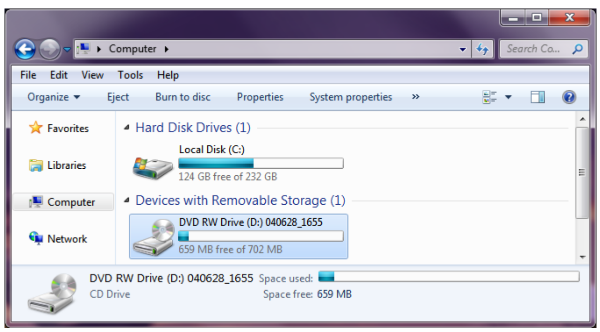

Figure 10: Active X CD

2. Right click the setup.exe application and choose "Properties" per Figure 11. Check the box to install the software in compatibility mode and ensure Windows XP (Service Pack 3) is selected. Check the box to run as administrator, and then click "OK".

3. Run the setup.exe application.

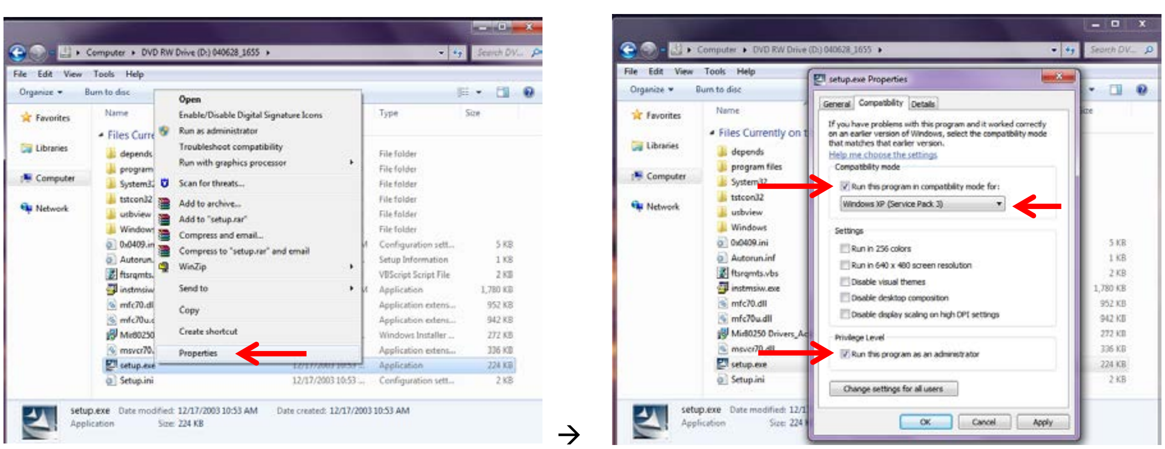

Figure 11: Run Active X Installer

4. Click “Next” to begin the installation process, as shown in Figure 12.

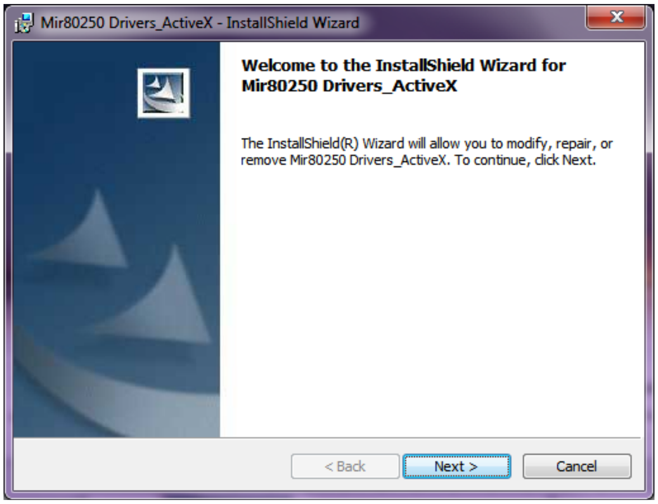

Figure 12: Begin Active X Installation

5. Select “Modify” and click “Next” per Figure 13.

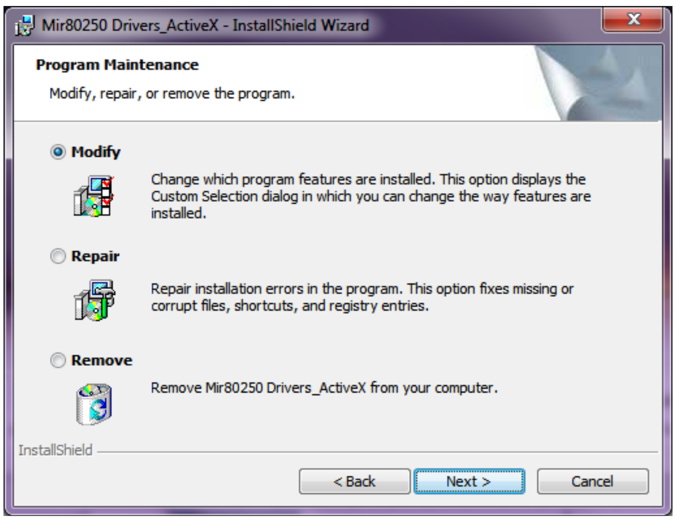

Figure 13: Select Type of Active X Installation

6. Highlight “Mir80350_Drivers_Active” and click “Next” per Figure 14.

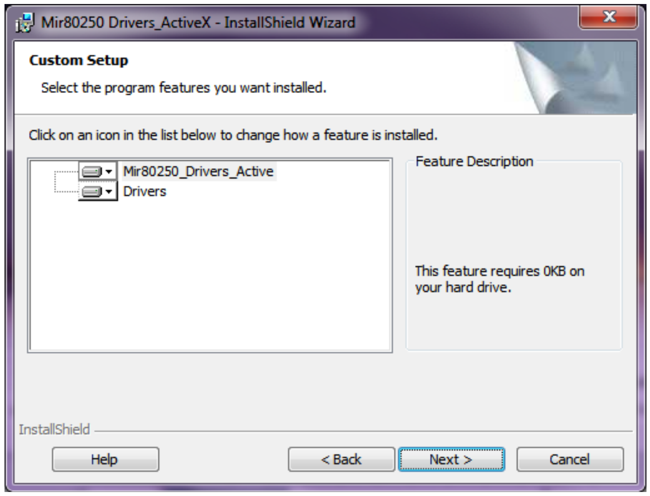

Figure 14: Select Active X Setup

7. Click “Next” as shown in Figure 15 to being running the installer.

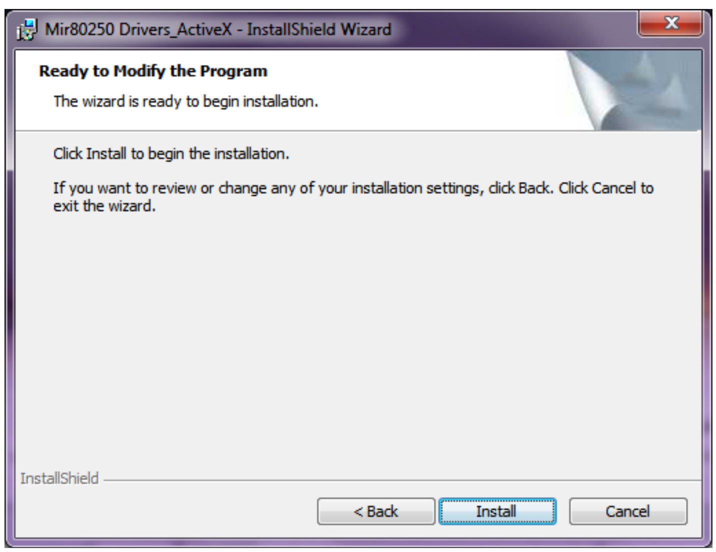

Figure 15: Run Active X Installer

8. When the installation is complete, the screen shown in Figure 16 will appear. Click "Finish".

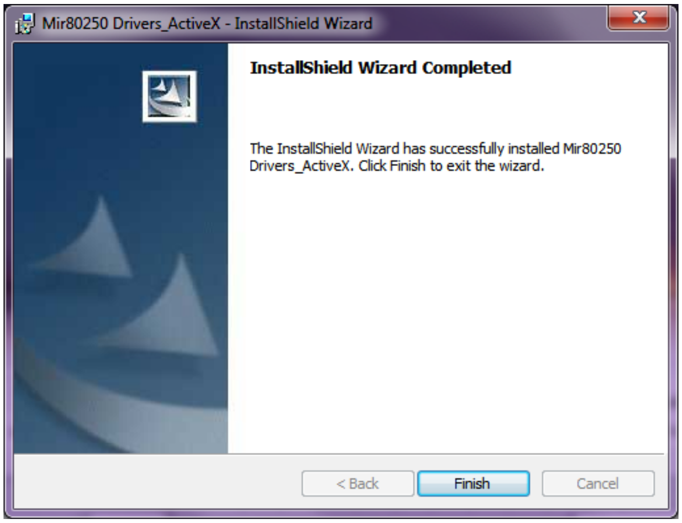

Figure 16: Active X Installation Complete

9. The Active X installation is now complete. However, communication to the instrument cannot be established until the MIRMat software installation has also been completed. If the error message shown Figure 17 appears, click OK. This message only appears on certain operating systems.

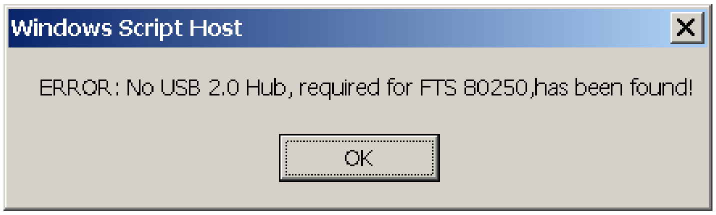

Figure 17: Active X Communication

10. <u>WINDOWS 7 USERS ONLY</u>:
Copy the following files (shown in Figure 18) from the CD to the computer's desktop.

- mfc70.dll
- mfc70u.dll
- msvcr70.dll

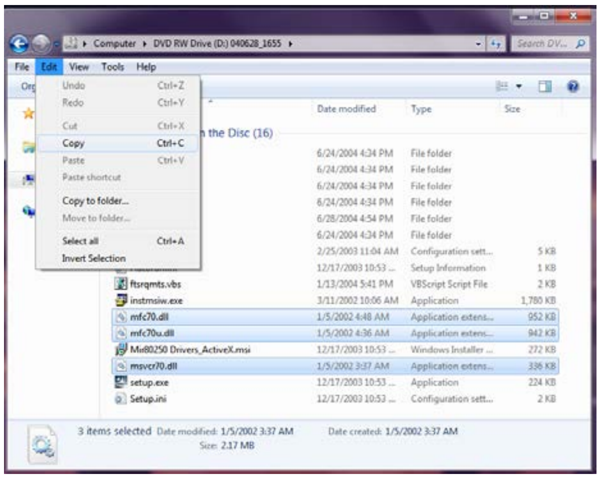

Figure 18: Copy dll Files

11. Remove the CD from the computer's CD-ROM drive, place it back into its case and store in a safe location.

12. Continue to Section 5 to install the MIRMat software.

5 MIRMAT SOFTWARE INSTALLATION

5.1 COMPUTER PRIVILEGES

The individual performing the installation must have administrator privileges for the computer. When installing onto a Windows 7 computer, the installation must be run in compatibility mode for Windows XP Service Pack 3.

5.2 MIRMAT SOFTWARE INSTALLATION PROCEDURE

This section will guide the user through the software installation process. Please note that the Figures shown are based upon an installation performed using a Windows XP operating system. Do not connect the USB cable to the computer until directed to do so in a later section of this manual.

13. Insert the MIRMat software CD into the computer's CD-ROM drive. Open the contents of the CD.

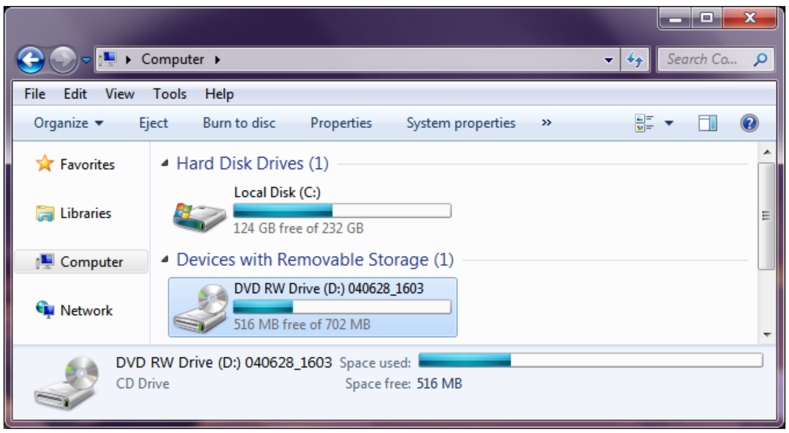

Figure 19: MIRMat CD

14. Right click the setup.exe application and choose “Properties” per Figure 20. Check the box to install the software in compatibility mode and ensure Windows XP (Service Pack 3) is selected. Check the box to run as administrator, and then click “OK”.

15. Run the setup.exe application.

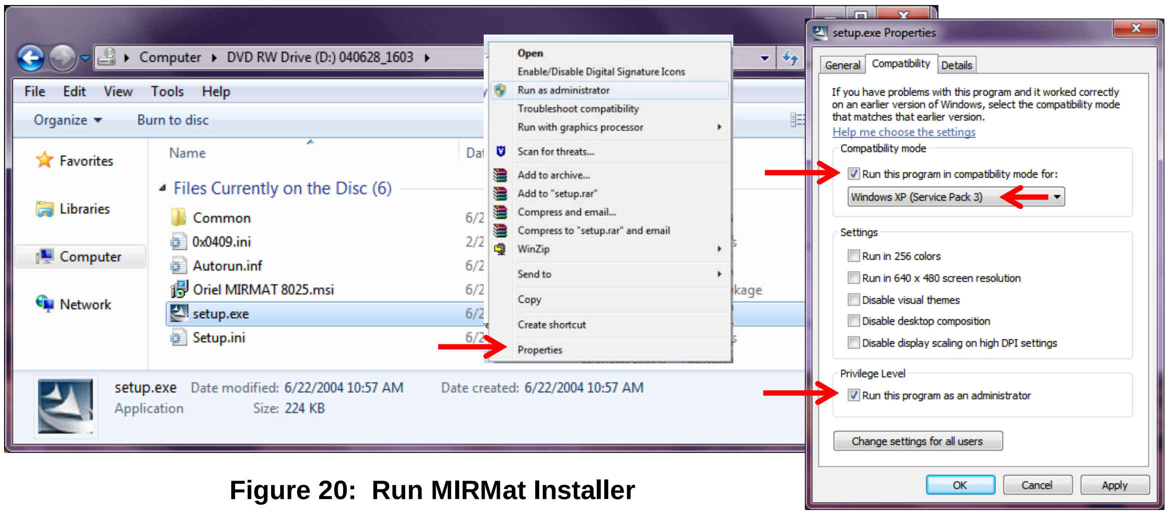

Figure 20: Run MIRMat Installer

16. A window will appear to indicate configuring of the installer, as shown in Figure 21. This may take a few minutes.

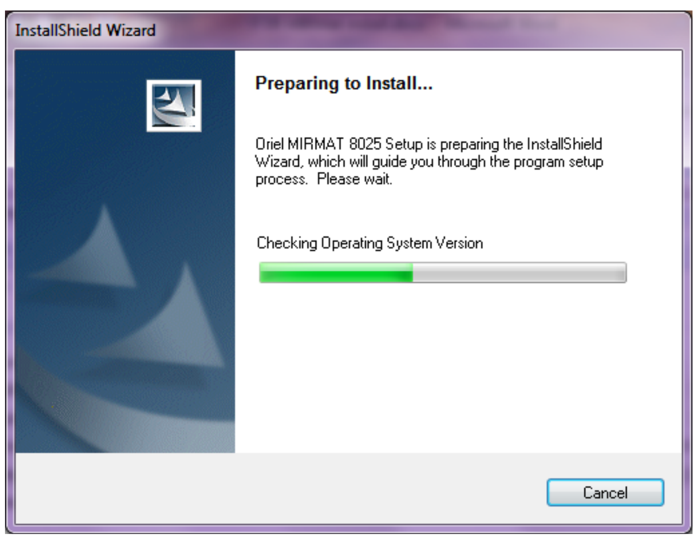

Figure 21: Configuring MIRMat Installer

17. Click “Next” to begin the installation process, as shown in Figure 22.

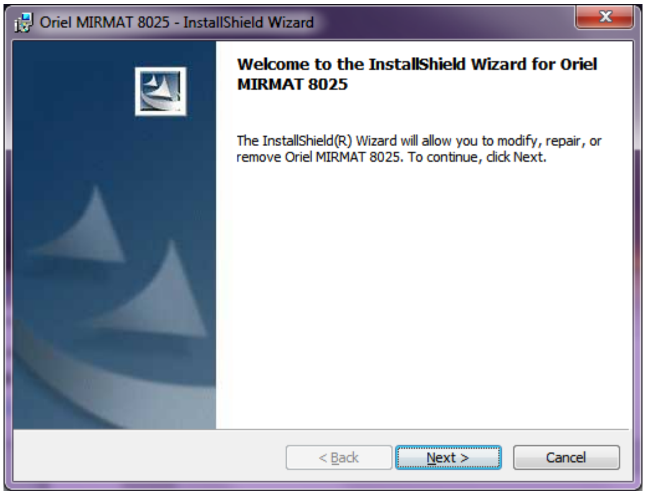

Figure 22: Begin Active X Installation

18. Select “Modify” and click “Next” per Figure 23.

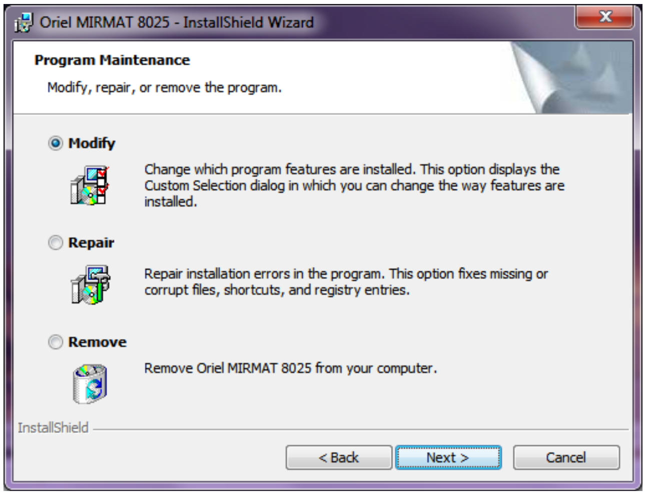

Figure 23: Select Type of MIRMat Installation

19. Highlight “Mir80350_Drivers_Active” and click “Next” per Figure 24.

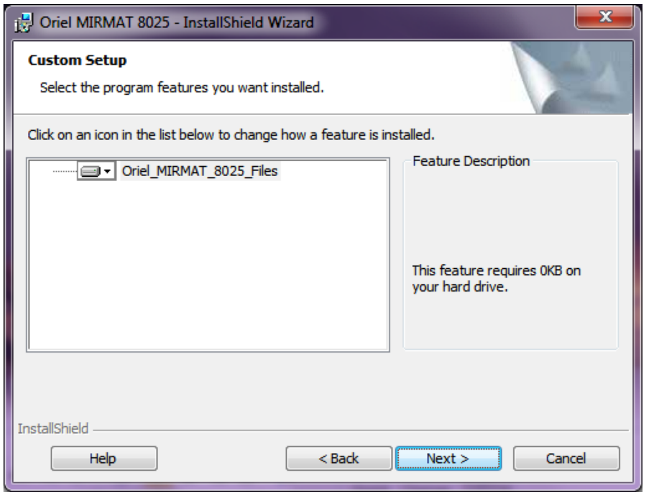

Figure 24: Select MIRMat Setup

20. Click “Next” to begin the installation process, as shown in Figure 25.

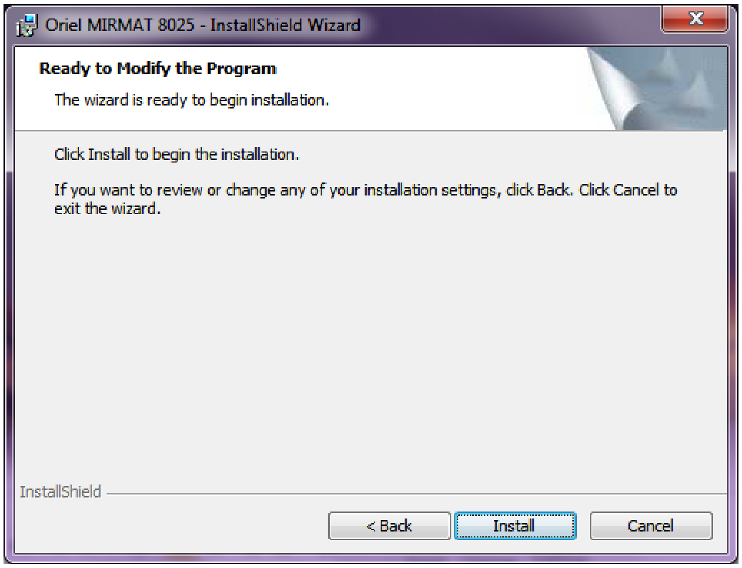

Figure 25: Run MIRMat Installer

21. When the installation is complete, the screen shown in Figure 16 will appear. Click "Finish".

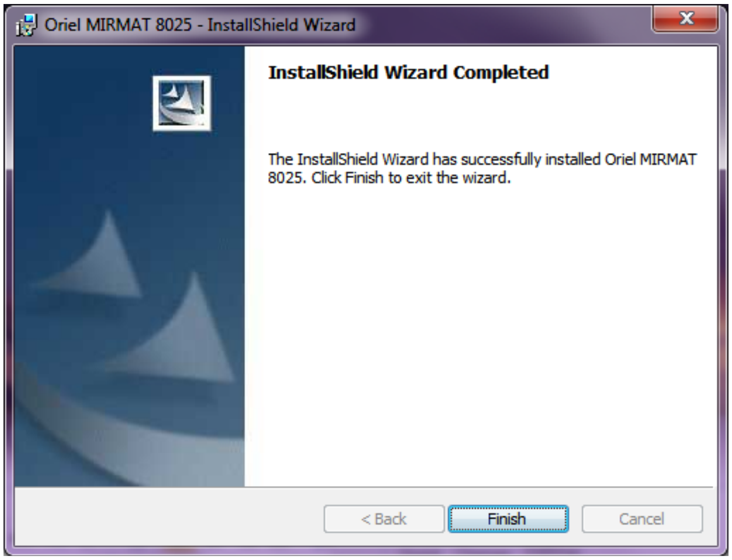

Figure 26: MIRMat Installation Complete

22. Remove the CD from the computer's CD-ROM drive, place it back into its case and store in a safe location.

23. <u>WINDOWS 7 USERS ONLY</u>:
Paste the .dll files listed below from the computer's desktop to the directory listed here. Failure to perform this step will result in a "MATLab Runtime Error" message appearing when opening the MIRMat software.

C:\Windows\System32

- mfc70.dll
- mfc70u.dll
- msvcr70.dll

24. Continue to Section 6 to install the FT-IR instrument driver.

6 FT-IR INSTRUMENT DRIVER INSTALLATION

6.1 COMPUTER PRIVILEGES

The individual performing the installation must have administrator privileges for the computer.

6.2 FT-IR DRIVERS INSTALLATION PROCEDURE (WINDOWS XP)

This section will guide the user through the driver installation process. Please note that unless otherwise stated, the figures shown are based upon an installation performed using a Windows XP (Service Pack 3) operating system. For Windows 7 users, please refer to Section 6.3.

1. With the FT-IR scanner off, connect the USB cable from the scanner to the computer.

2. Apply power to the scanner.

3. The Found New Hardware Wizard should automatically open in Windows XP. If installing onto a Windows 7 32-bit operating system, go to the device manager and locate "VSE-SPECTRA" under "Other devices". Right click and select "Update Driver Software…" from the menu.

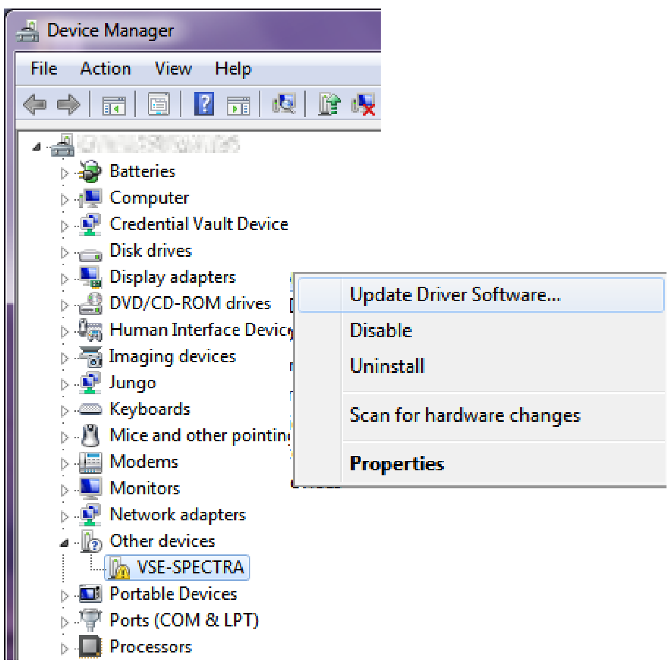

Figure 27: Updating Driver in Windows 7

4. If the screen appears as shown in Figure 28, select the option labeled “Yes, this time only. Click “Next” to proceed.

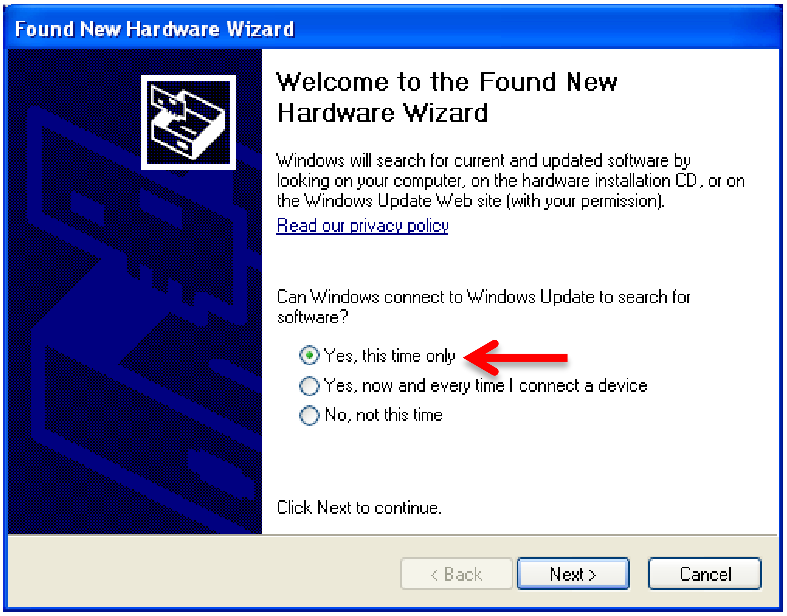

Figure 28: Found New Hardware Wizard

5. Check the option labeled “Install the software automatically (Recommended)”, as shown in Figure 29. Click “Next” to proceed.

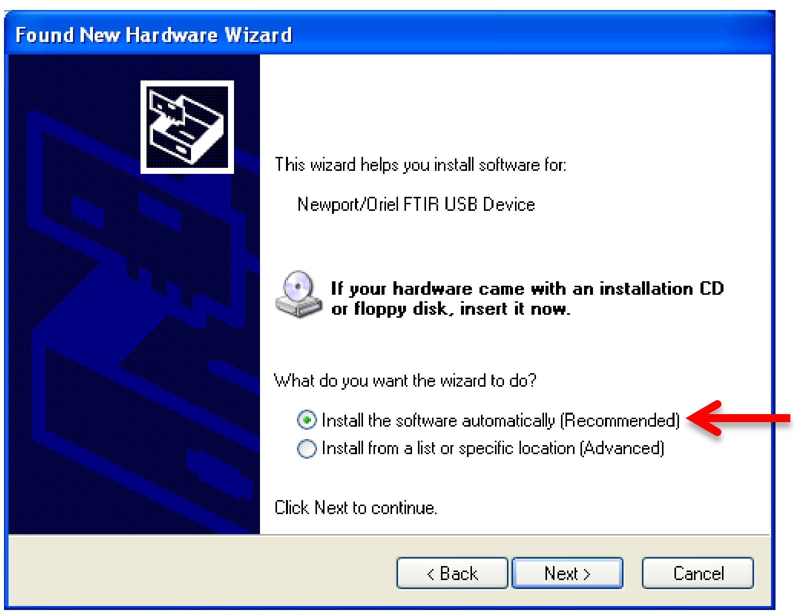

Figure 29: Install Software Automatically

6. The window shown in Figure 30 may appear. Click “Continue Anyway”.

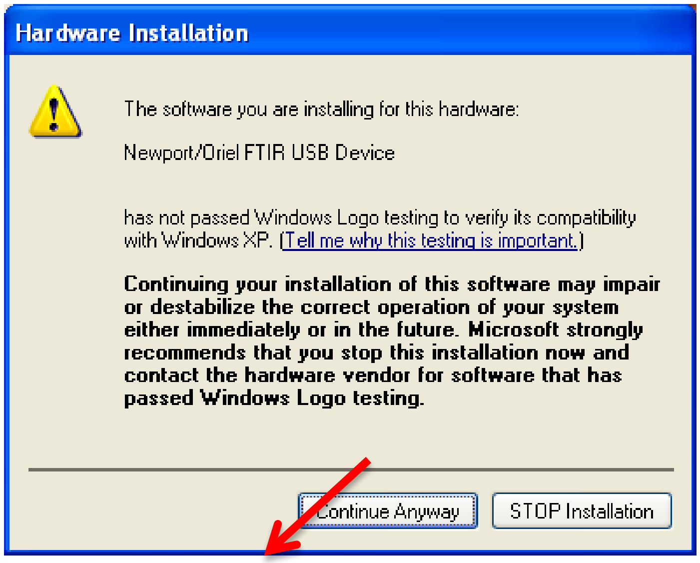

Figure 30: Windows XP Signed Driver Prompt

7. Installation of the FT-IR instrument driver will now begin. Refer to Figure 31.

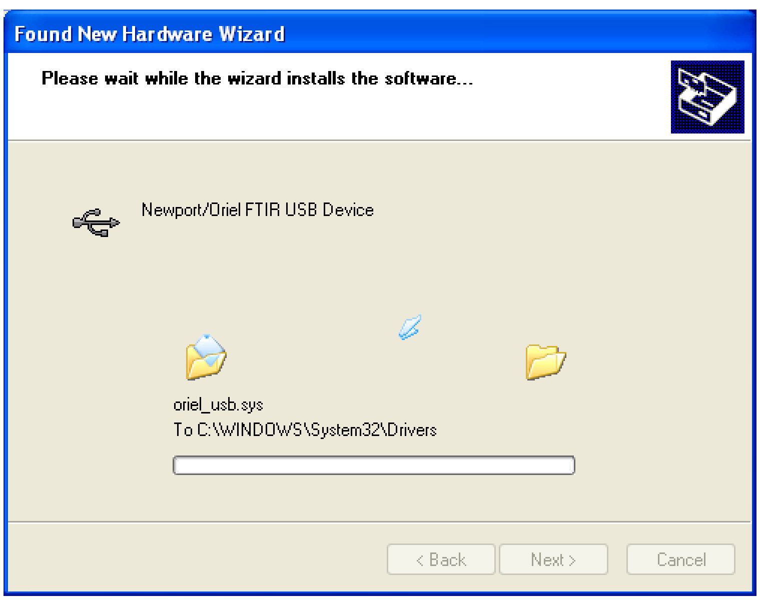

Figure 31: Installing Instrument Driver

8. Upon completion, the screen shown in Figure 32 will appear. Click “Finish”. If successful, the instrument will now appear in the Windows Device Manager under USB Devices.

Figure 32: Instrument Driver Installation Complete

6.3 FT-IR DRIVERS INSTALLATION PROCEDURE (WINDOWS 7)

This section will guide the user through the driver installation process. Please note that unless otherwise stated, the figures shown are based upon an installation performed using a Windows 7) operating system. For Windows XP users, please refer to Section 6.2.

1. With the FT-IR scanner off, connect the USB cable from the scanner to the computer.
2. Apply power to the scanner.
3. Go to the device manager and select the listing for the FTIR.
4. Right click on the FTIR and select Update Driver Software…

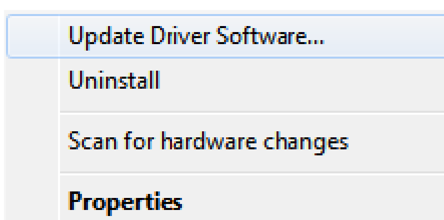

Figure 33: Update Driver Software

5. Choose Browse my computer for driver software.

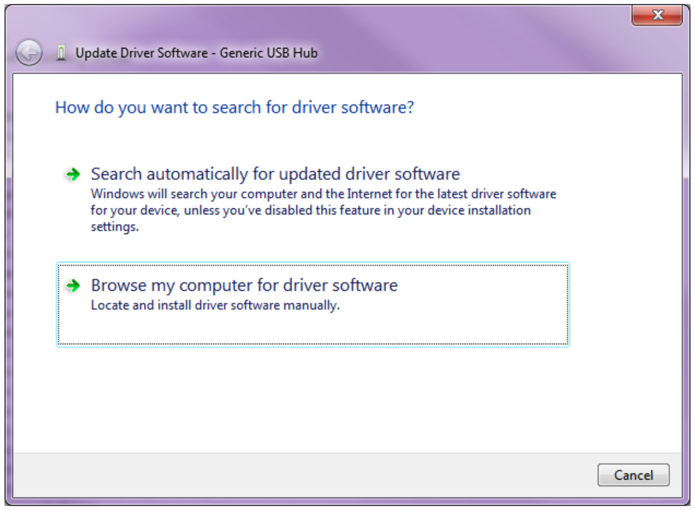

Figure 34: Browse for Driver Software

6. Choose Let me pick from a list of device drivers on my computer.

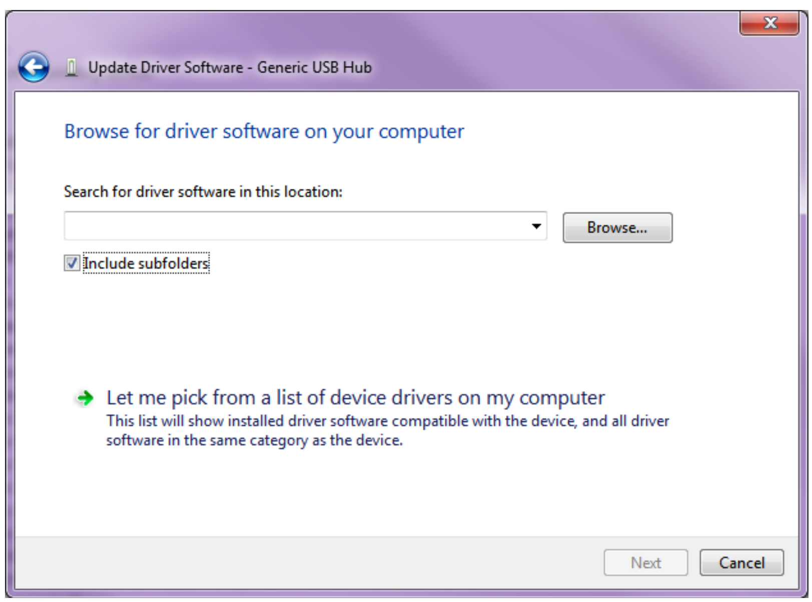

Figure 35: Pick from a List of Drivers

7. Choose Have disk.

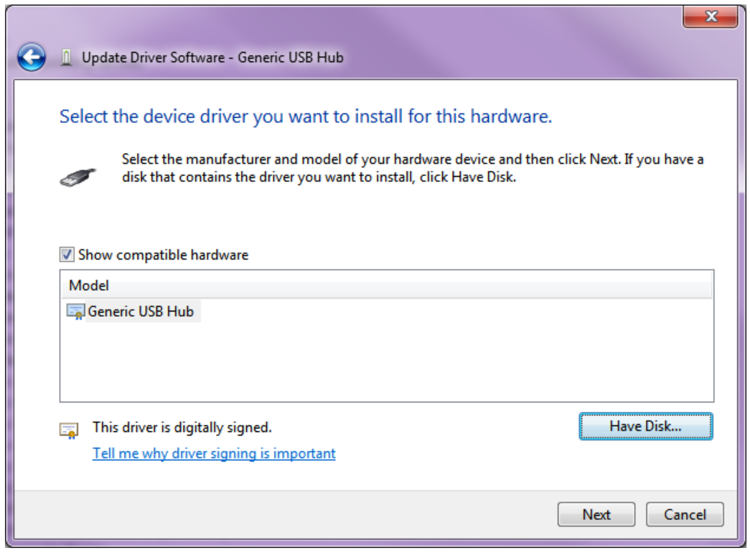

Figure 36: Have Disk…

8. Browse to and select C:\windows\vsespectra.inf.

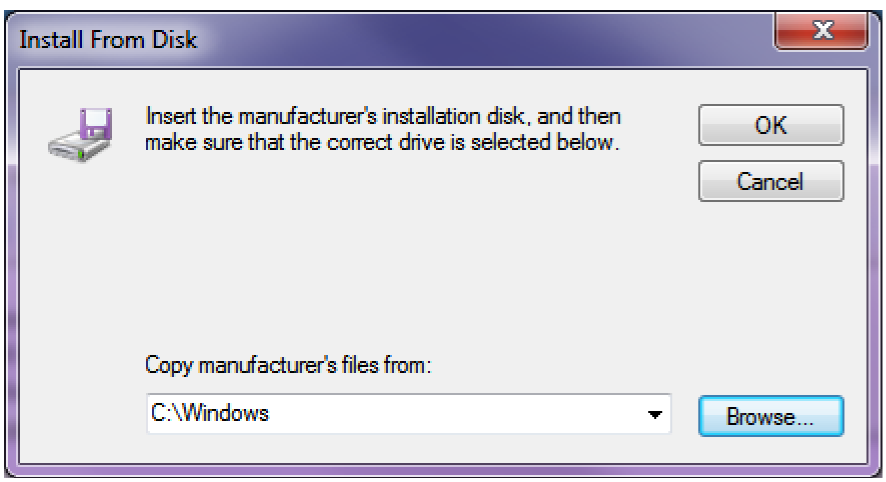

Figure 37: Selecting .inf File

7 GETTING STARTED WITH MIRMAT

7.1 INITIAL HARDWARE CHECK

The MIR8035 is designed to be a flexible, modular system consisting of the scanner and various attachments such as IR sources, detectors, etc. The user's manual describes the basic operation of the system and its software.

Turn on the power switch of the scanner and other accessories. Click on the MIRMat icon in the Start Menu to open the software. Once the software recognizes the instrument, the scanner shall operate in Laser Mode. If the scanner has completely stopped, refer to Section 14.1 for the beamsplitter alignment procedure.

Check the signal values and phase on the scanner's LCD. Both A and B signal readings must be above 25% with a difference of less than 5%. The phase must be 88° to 92°. If the values displayed on the LCD after a 30 minute scanner warm-up do not meet the above criteria, refer to Section 14.1 for the beamsplitter alignment procedure and/or Section 14.2 for phase adjustment.

Click on the MIRMat icon in the Start Menu to open the software.

Figure 38: MIRMat Icon

Figure 39: MIRMat Software

7.2 SOFTWARE WINDOWS

Two windows will open in the MIRMat software, as shown in Figure 40. The FTS_AX Container (Active X) window is shown on the right.

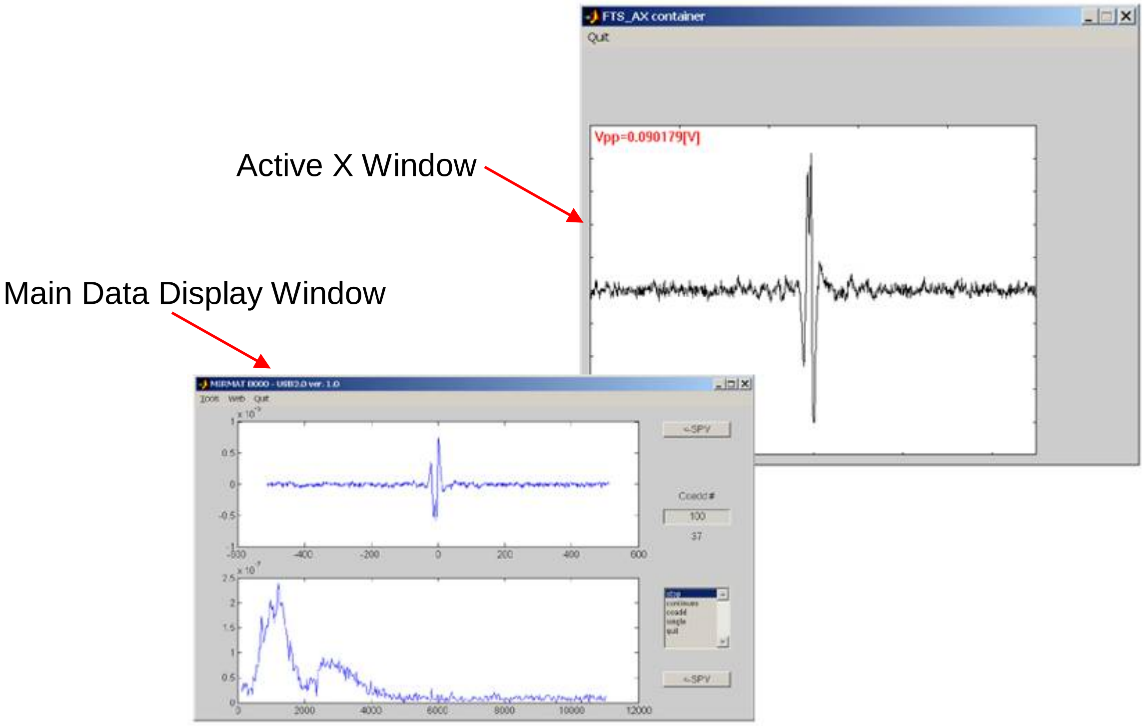

Figure 40: MIRMat Windows

7.3 SETTING INSTRUMENT PARAMETERS

Using the mouse, right click on the FTS_AX Container window to bring up the FTS_AX Control Properties. Select "Stop" on the MIRMat main screen before altering any of the parameters. It is suggested to adjust the parameters in the following order:

1. Resolution
2. Velocity
3. Oversampling

These settings must be adjusted prior to taking any data.

7.3.1 Resolution

The resolution is expressed in wave number (cm^{-1}) and is uniform throughout the entire spectral range. Choices are 40, 25, 15 and 5 cm^{-1}. The higher the resolution, the longer the acquisition speed. A sufficient resolution for most measurements is 5 cm^{-1}.

To convert from wavenumber to nanometers or visa versa, use the following formula:

$$x \text{ nm} = 10{,}000{,}000 / x \text{ cm}^{-1}$$
$$y \text{ cm}^{-1} = 10{,}000{,}000 / y \text{ nm}$$

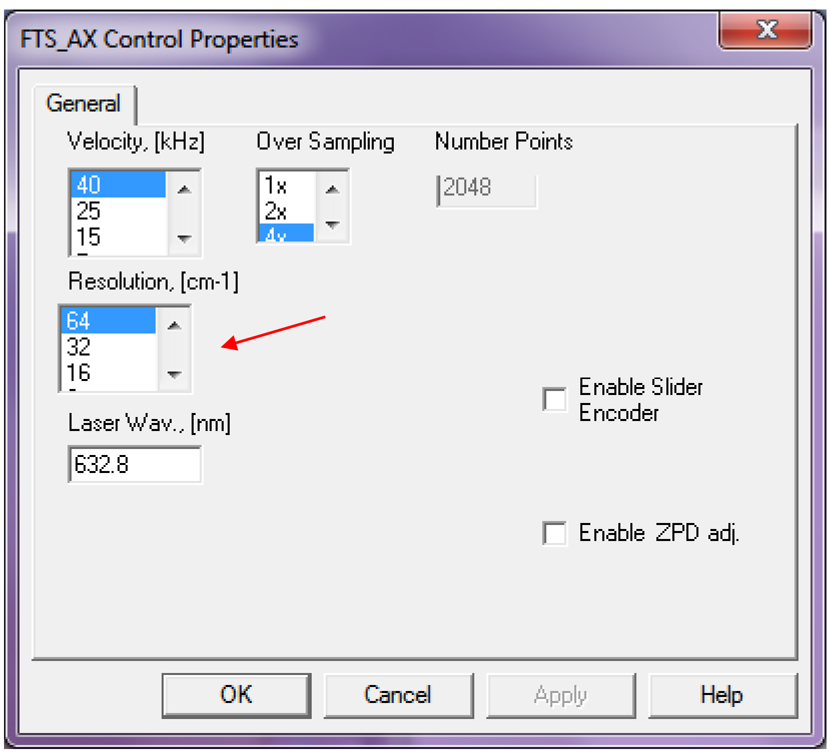

Figure 41: Setting Resolution

7.3.2 Velocity

Velocity is defined as the speed at which the scanning mirror moves. Choices are 40, 25, 15 and 5 KHz.

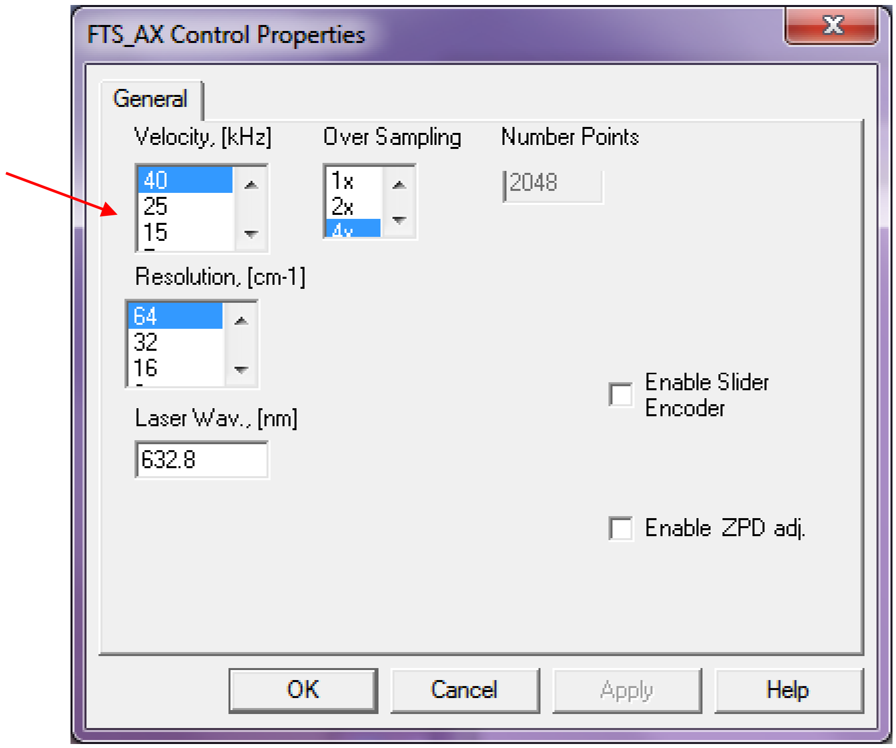

Figure 42: Setting Velocity

7.3.3 Oversampling

Oversampling choices are 1x, 2x and 4x.

Please refer to Section 20 (Appendix A) for more information on oversampling.

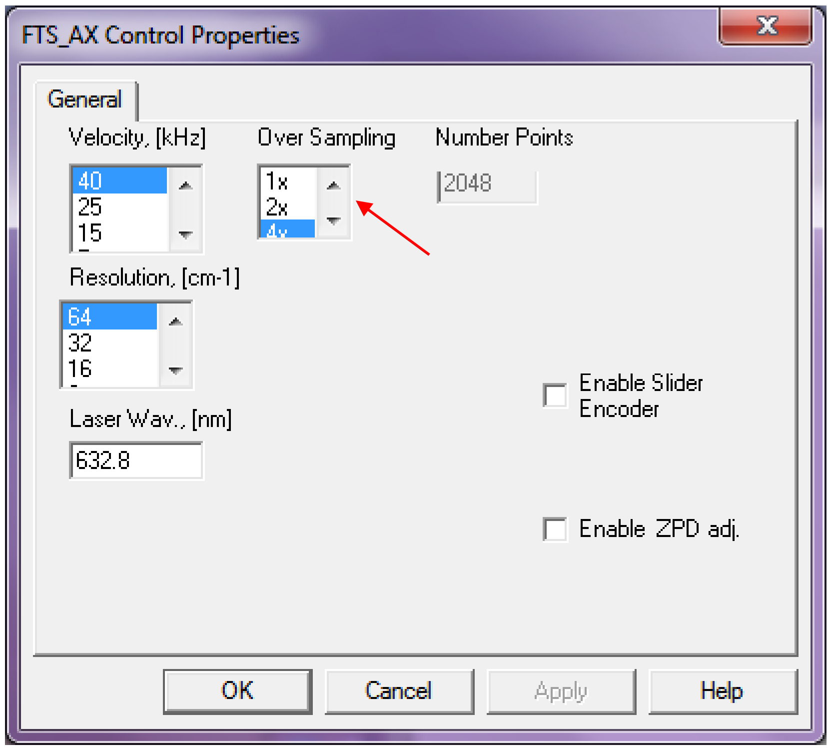

Figure 43: Setting Oversampling

7.4 SCANNER MODES

The MIR8035 scanner has two modes of operation. Upon powering up the scanner, it operates in encoder mode. The scanner will remain in encoder mode until it receives a command to switch to laser mode. When the MIRMat software is in use or the Active X control is loaded, the scanner is placed in laser mode by default when applying power.

7.4.1 Encoder Mode

In this mode, the scanner utilizes an encoder to control motion. Motion continues regardless of laser alignment or status. This mode is for beam splitter alignment and troubleshooting only. It cannot be used for data acquisition.

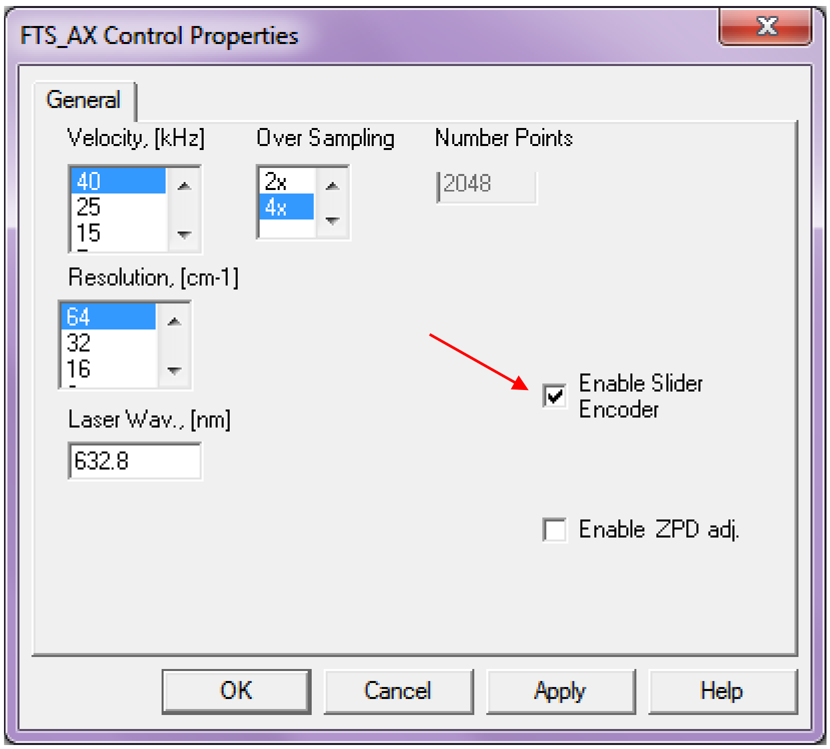

Figure 44: Enabling Encoder Mode

7.4.2 Laser Mode

In laser mode, the scanner utilizes the laser to control motion. Therefore, the laser must be operating and the beam splitter must be correctly aligned. The scanner must be in laser mode to acquire data.

7.5 MAIN DATA DISPLAY

Prior to taking any data, the Resolution, Velocity and Oversampling must be set (refer to Section 7.3 for more information).

When data is taken, the screen displays both the interferogram and spectrum.

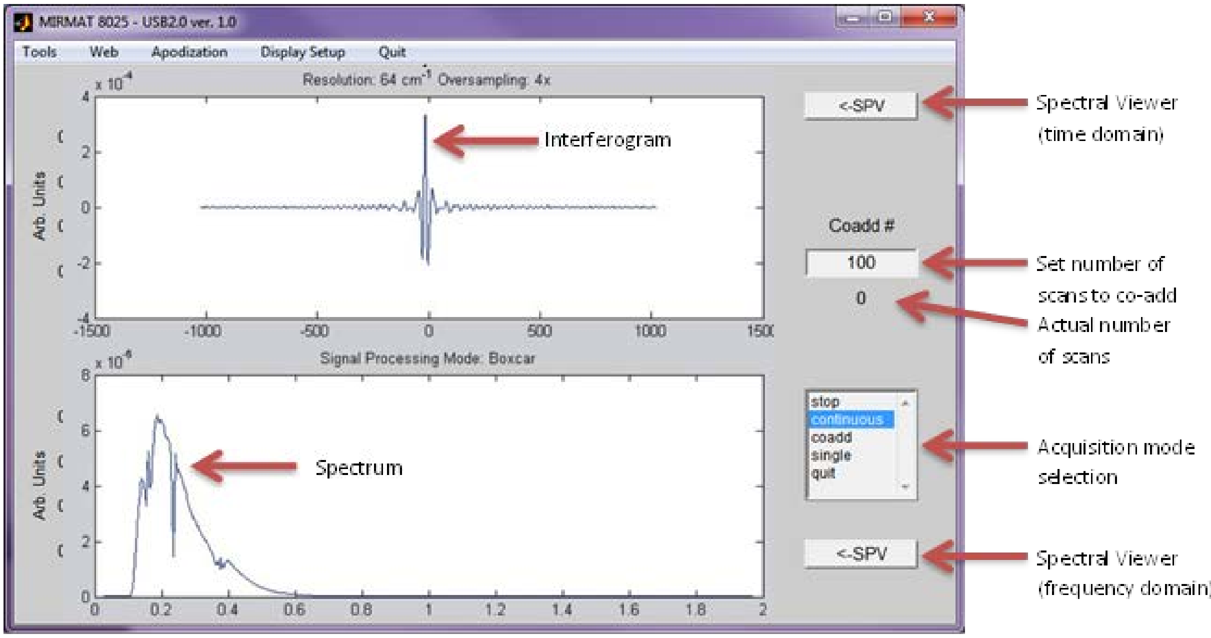

Figure 45: Interferogram and Spectrum Display

The top plot in this window is the interferogram and the bottom is the spectrum. The screen displays the number of scans and loops. The status and counter fields display real-time information.

This window is used to display a quick view of the data, in both time domain and frequency domains. To perform calculations on the scan, display data in the Spectral Viewer. This is discussed in Sections 7.8 and 7.14.

7.6 MAIN DISPLAY MENU BAR FUNCTIONS

The menu bar pull-down menus are found at the top of the main display window.

Tools: **Zoom In**
Zoom Out
Time Domain
Auto Scale X
Auto Scale Y
Frequency Domain
Auto Scale X
Auto Scale Y

Zoom in or out by clicking in the graph windows. Use the mouse to window around an area of interest on the graph when zooming in. To return to the original views, select the auto scaling commands for the time or frequency domain graphs.

Web: opens the default web browser and goes to the Newport website.

Apodization: **Boxcar**
Hanning
Triangular
Blackman
Hamming

Selecting one of the choices applies the window function to the graph. The interferogram data is still preserved in its natural acquisition format, while the spectrum is Fourier transformed with the selected windowing function.

Display Setup: **Freq. Domain Y Scale**
Linear
Log

By default, the y-axis scale of the frequency domain is linear.

Quit: exits the MIRMat application.

7.7 ACQUISITION MODES

When the software first opens, Stop is the default acquisition mode and the number of scans shown is zero highlighted in green. Other acquisition choices are: Continuous, Coadd, Single and Quit. Enter a number in the Coadd# field to set up how many scans to coadd, then select Coadd acquisition mode. The actual number of scans will increase until the limit is reached. Once completed, the actual number of scans is highlighted in red. If the Continuous mode is selected, the number of scans continues until Stop is selected. The Quit selection exits the application.

7.8 SPECTRAL DATA VIEWERS

In the main data display window, the time domain Spectral Viewer is accessed by clicking on the SPV icon located to the right of the time domain plot. Note that in this window, data is no longer being acquired. The spectral viewer is used to zoom, pan and perform calculations on the scan.

The frequency domain Spectral Viewer displays the last acquired spectrum. It is accessed by clicking on the SPV icon located to the right of the frequency domain plot. It has the same functions as the time domain Spectral Viewer, as well as a pull down menu used to select units. Available units for the x-axis are: μm, nm, cm^{-1}, MHz, eV, kcal/mol, kJ/mol and K.

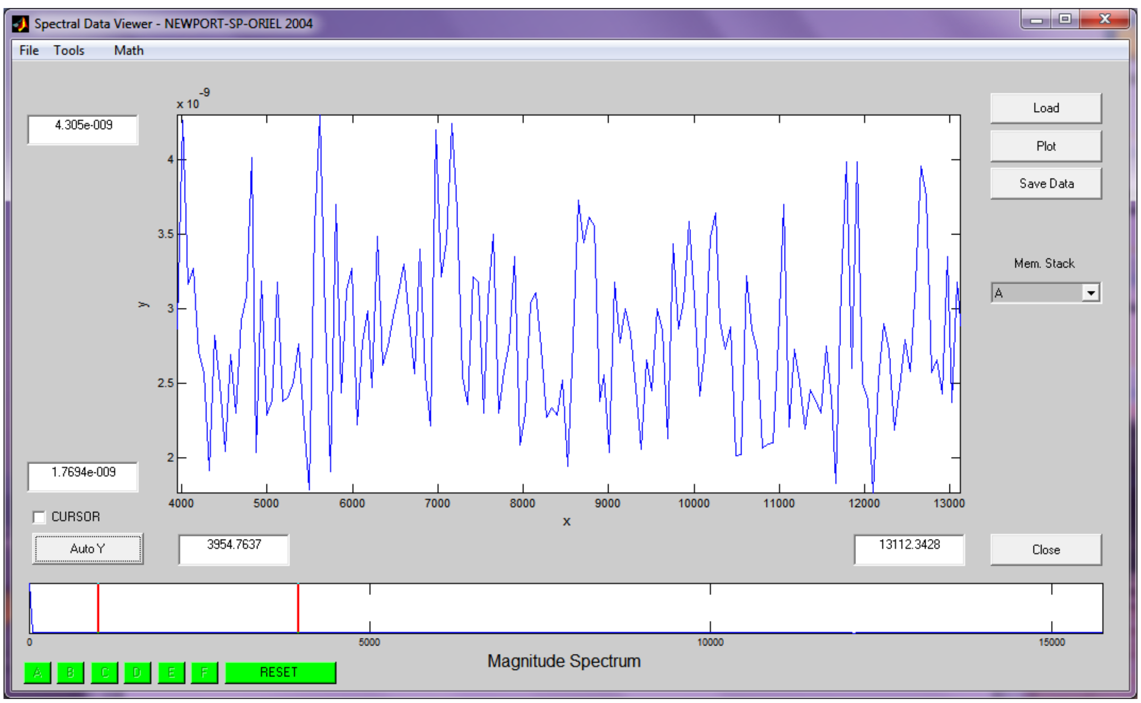

Figure 46: Time Domain Spectral Data Viewer

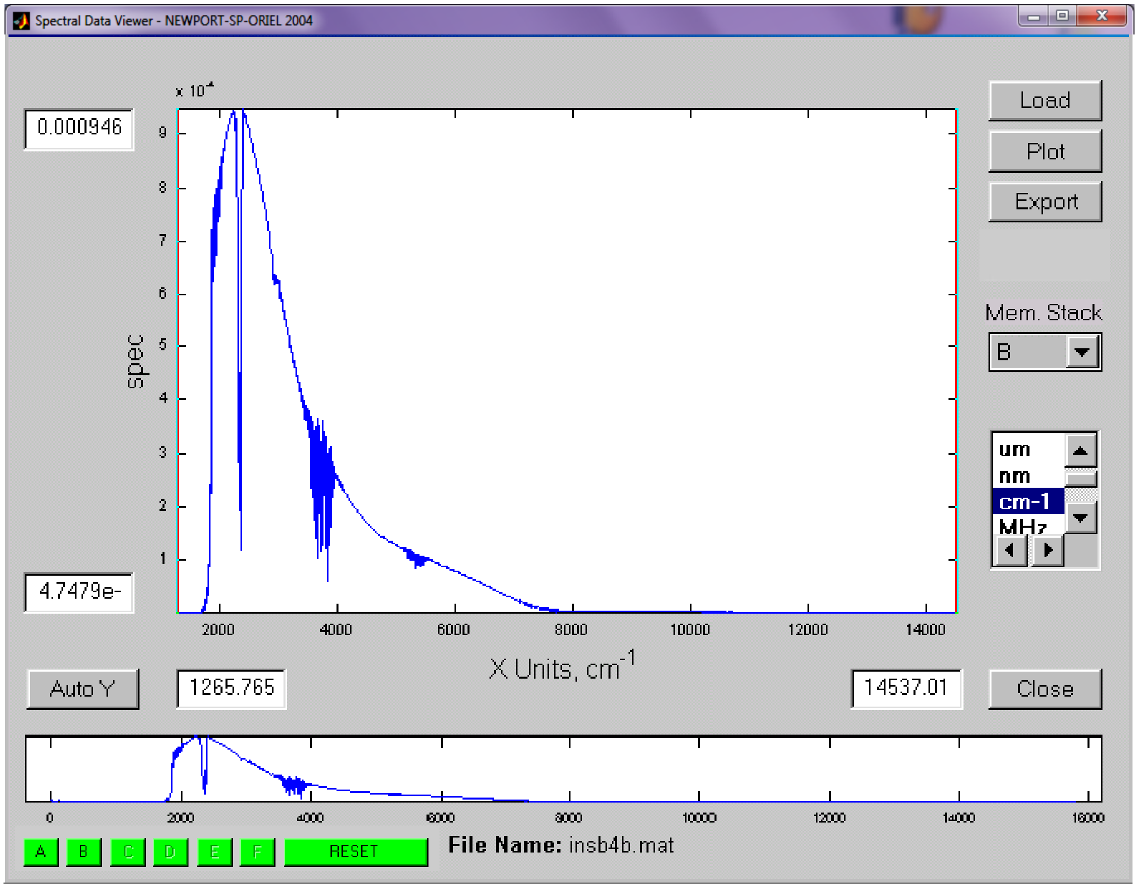

Figure 47: Frequency Domain Spectral Data Viewer

7.9 ZOOM, PAN AND SCALE

In the Spectral Viewer, one is able to adjust the scale of the data being displayed. The Auto Y icon can be used to restore the view of the data if it is off the chart area. Limit fields are present for both the x and y-axes. The upper limit must be greater than the lower limit, or else an error message will appear in a separate window. Click the Continue button in the error window to correct the limits. Clicking Quit exits the application.

Below the main display screen is a preview display with two vertical bars. These bars define the x-axis of the main display. Click and drag the bars to see the change in the x-axis. This area is used to zoom in on a specific area, or pan over a large area.

7.10 MEMORY STACK

The Memory Stack pulldown menu in the Spectral Viewer is used to store up to six (6) interferograms and spectra in temporary memory. Data that is stored in the memory stack can be recalled and mathematically manipulated in the MIRMat software.

The memory stack locations are referred to as A through F. To store the data, click the down arrow and then click on any letter from the Mem Stack field. Using a location containing previously saved data will overwrite that data. When the data is stored successfully, the popup window in Figure 48 appears briefly.

The status of the memory stack is displayed in the lower left corner of the Spectral Viewer window (refer to Figure 49). Letters appearing in black text indicate data is stored in that location. Clicking the Reset button clears the entire memory stack.

The memory stack is not the same as permanently saving the data on the computer's hard drive or other media – it temporarily stores data. When exiting the MIRMat software or closing the SPV window, the data stored in the memory stack is erased. Refer to 8 for information on saving data.

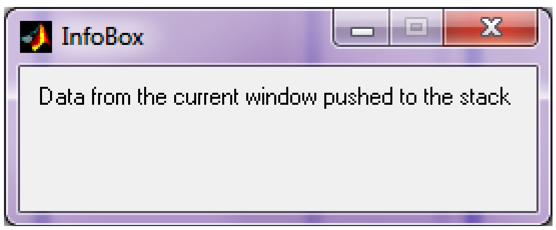

Figure 48: Data Stored in Memory Stack

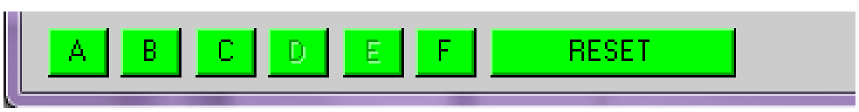

Figure 49: Data Stored in Locations A, B, C and F

7.11 CURSOR

A cursor feature is present in the time domain SPV. Click the checkbox to enable it. By placing the cursor in the scan window, the values of the x and y-axes are displayed. Uncheck the box to remove the cursor from the screen.

7.12 SPV MENU BAR FUNCTIONS

The menu bar pull-down menus are found at the top of the main display window.

File: **Close**
Print…

Printing saves a screen capture of the SPV window. Close exits the SPV, but not the entire application.

Tools: **Zoom In**

Zoom in by clicking in the graph windows. Use the mouse to window around an area of interest on the graph when zooming in.

Math: **Function A ? B**
FFT
- **1x oversampled interf.**
- **2x oversampled interf.**
- **4x oversampled interf.**
- **Default from Instrument**

Decimate
- **Decimation by 2**
- **Decimation by 4**
- **Decimation by 8**

Semilog Y (changes to Linear Y when selected)
DIFF
Normalize
Detrend
Apodization
- **Boxcar**
- **Hanning**
- **Triangular**
- **Blackman**
- **Hamming**

When selecting any of the FFT choices, the bottom of the screen will show “Magnitude Spectrum” and AutoScale can be enabled. DIFF indicates a first order difference is applied. At least one location of the Memory Stack need to be filled prior to selecting Function A ? B. The memory stack locations chosen do not necessarily have to be A and B. If at least one location is filled, the Spectral Calculator will appear. Refer to 7.14 on using the Spectral Calculator.

7.13 MATH MENU DEFINITIONS

DECIMATE Resample data at a lower rate after low pass filtering.
Y = DECIMATE(X,R) re-samples the sequence in vector X at 1/R times the original sample rate. The resulting re-sampled vector Y is R times shorter, LENGTH(Y) = LENGTH(X)/R.
DECIMATE filters the data with an eighth order Chebyshev Type I low pass filter with cutoff frequency .8*(Fs/2)/R, before re-sampling.

DETREND Remove a linear trend from a vector, usually for FFT processing.
Y = DETREND(X) removes the best straight-line fit linear trend from the data in vector X and returns it in vector Y. If X is a matrix, DETREND removes the trend from each column of the matrix.

DIFF Difference and approximate derivative.
DIFF(X), for a vector X, is [X(2)-X(1) X(3)-X(2) ... X(n)-X(n-1)].

FFT Discrete Fourier transform.
FFT(X) is the discrete Fourier transform (DFT) of vector X.
FFT requires knowledge of over sampling parameter. If over sampling selection will not match native sampling of interferogram the resulted X scale will have no physical meaning in terms of Wavenumber assignment

7.14 SPECTRAL CALCULATOR

If at least one location is filled in the Memory Stack, the Spectral Calculator may be used to perform mathematical calculation. Open the Spectral Calculator by going to Math → Function A?B in the SPV window.

Functions provided are:

- -LOG10
- CALCULATE
- SQRT
- INVERT
- NEGATE
- ABSOLUTE

Choices for the first and second variables are A through F of the memory stack, 0 or 1.

Mathematical operators are addition, subtraction, multiplication and division.

Clicking on the equal sign performs the calculation. The data is stored in the stack specified to the right of the equal sign. Note that the Spectral Calculator result will override anything already stored in that location.

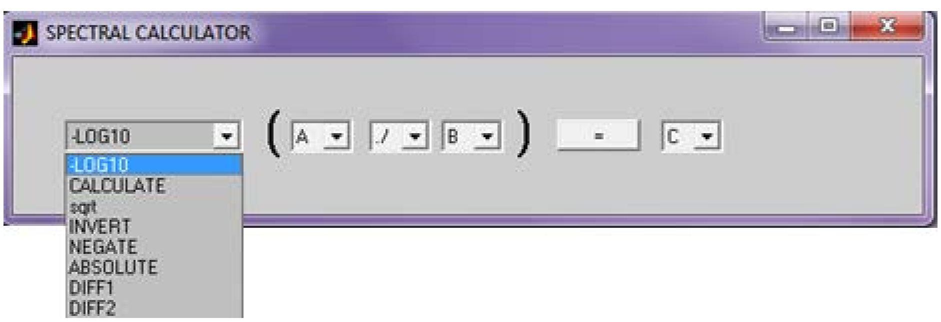

Figure 50: Spectral Calculator

7.15 PLOTTING FROM SVG WINDOW

Each time the Plot button is clicked, a plot is added to the plot window. This can result in numerous plots being displayed at once, for comparison.

7.16 LOADING A FILE FROM SVG WINDOW

Clicking the Load button in the SVG window brings up the following:

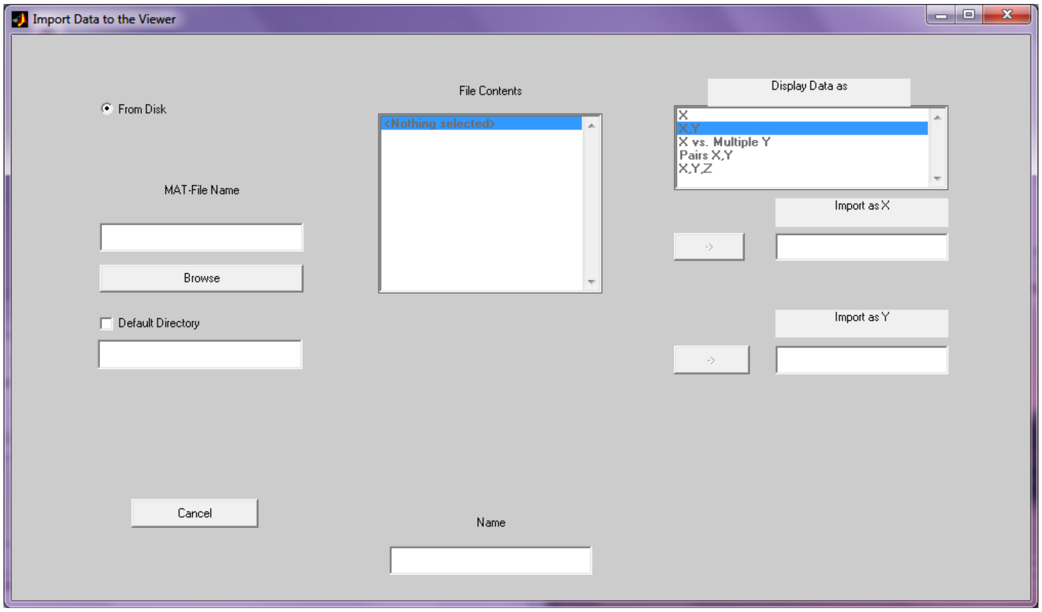

Figure 51: Loading a .mat File

Browse and select a .mat file. Display data as X, Y. Under File Contents, highlight X. Click the right arrow to select it as the Import as X field. Repeat for the Y-axis. Once this is done, the OK button appears so that the file can now be imported.

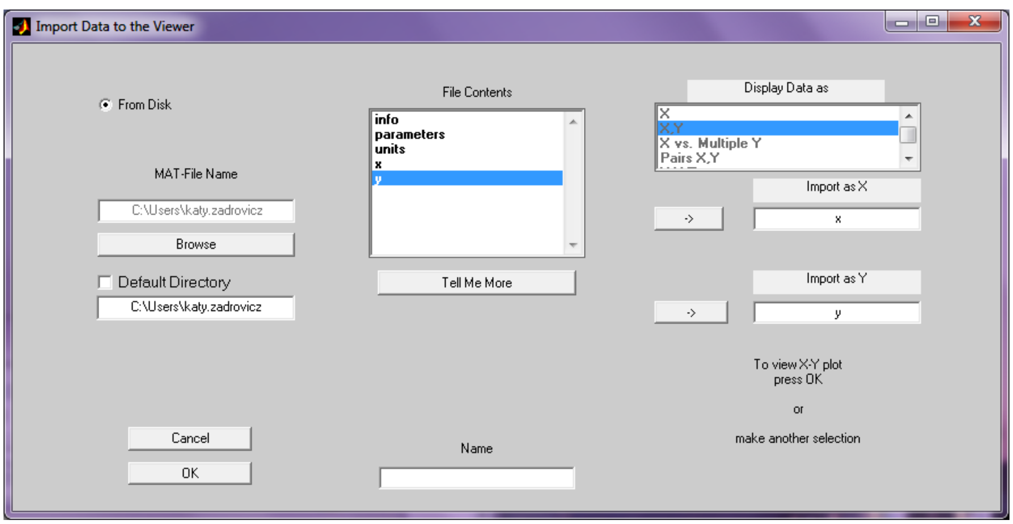

Figure 52: Parameters for Loading a *.mat File

8 OPENING, SAVING AND PLOTTING DATA

8.1 PLOT WINDOW MENU BAR FUNCTIONS

The plot window is opened by clicking the Plot button in the SPV. The menu bar pull-down menus are found at the top of the main display window.

File: **Open…**
Close
Save
Save As…
Export…
Page Setup…
Print Setup…
Print Preview…
Print…

Tools: **Edit Plot**
Zoom In
Zoom Out
Rotate 3D
Default Scale
X
Y

When selecting a command under the Tools menu in the plot window, that option will remain checked. For example, if the Zoom In command is chosen, any time the mouse is clicked inside the plot window, the view will be magnified. To uncheck, go back to the Tools menu and uncheck the command or select another command.

Get Data from SPV: refreshes the plot from a continuously running scan.

Plot Mode: **Grid off**
Grid on
Box off
Box on
Axis on
Axis off
Remove Last Plot
Clear All

Web: opens the default web browser and goes to the Newport website.

Close: closes the plot window.

8.2 OPENING A FILE

In the plot window, File → Open allows one to select a .fig file, which opens in a separate window.

8.3 SAVING AND EXPORTING

The Save and Save As commands under the File pulldown menu allow the plot to be stored as a .fig file. The MATLab .fig file is a binary format to which one may save figures so that they can be opened in subsequent MATLab sessions. The whole figure, including graphs, graph data, annotations, data tips, menus and other user interface controls, is saved. The only exception is highlighting created by data brushing. As a MATLab based software application, MIRMat supports this type of file.

Exporting a file allows the plot to be saved in various graphic file formats, such as .emf, .bmp, .jpg, etc. The exported file is not an entire screen capture of the plot window. This function exports and saves the plot window and values for the x and y-axes.

8.4 ZOOMING IN/OUT, AUTO SCALING PLOT

Zoom In and Zoom out allow the user to click on the plot to change the view. Zoom In also allows the user to create a window around an area for closer examination. Default scale X or Y commands allow the view to be auto scaled, provided the view is not a 3D rotated plot.

8.5 3D PLOTTING

Select Plot View →3D-View.

To display a 3D plot at a custom viewing angle, select Tools → Rotate 3D Plot. Click and drag the mouse in the plot window to adjust the view as a 3D graph. In order to return to the default 2D plot, continue to drag the plot.

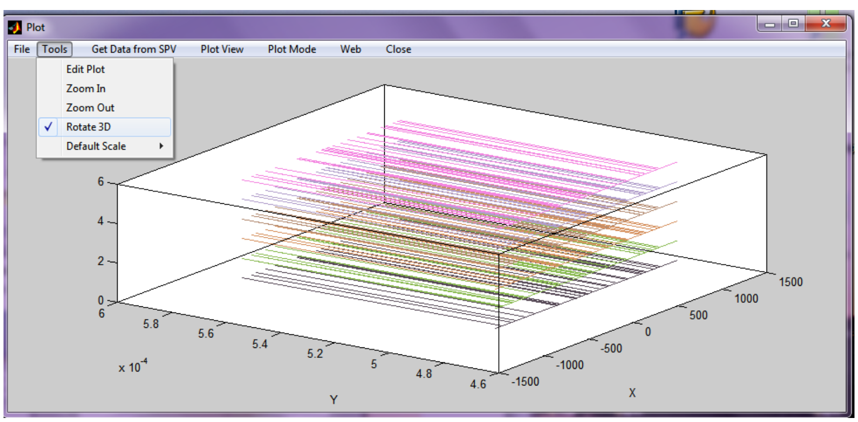

Figure 53: 3D Rotated Plot

8.6 GRID AND AXIS SETTINGS

The Grid can be displayed only when the Axis display is turned on.

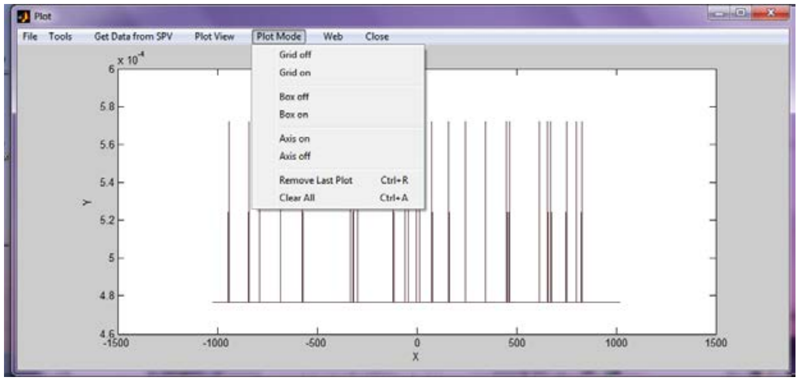

Figure 54: Axis On, Grid Off

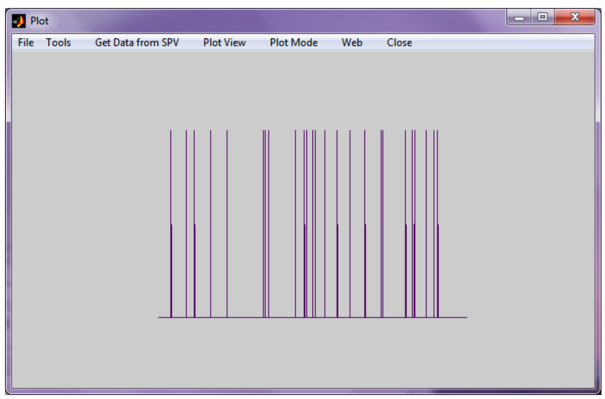

Figure 55: Axis Off

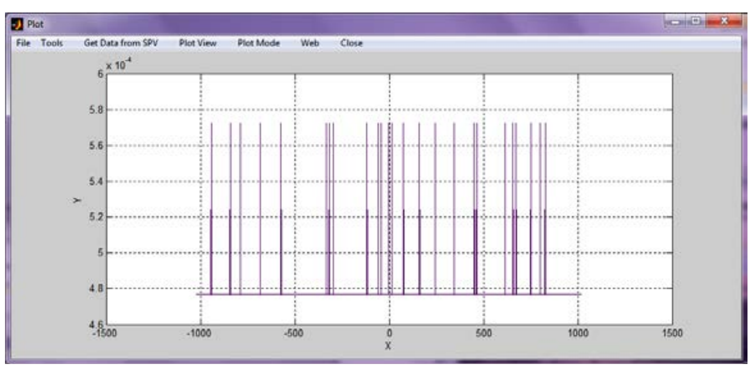

Figure 56: Axis On, Grid On

8.7 CLEARING PLOTS

If the Plot button was clicked multiple times in the SVG window, multiple plots will appear together. In the plot window, go to Plot Mode → Remove Last Plot to erase the last plot. Clear All will remove all plots and leave a blank plotting window.

8.8 PLOT LEGEND

Right click in the plot area and select Show Legend. Right click in the plot area once more to select Hide Legend, if desired

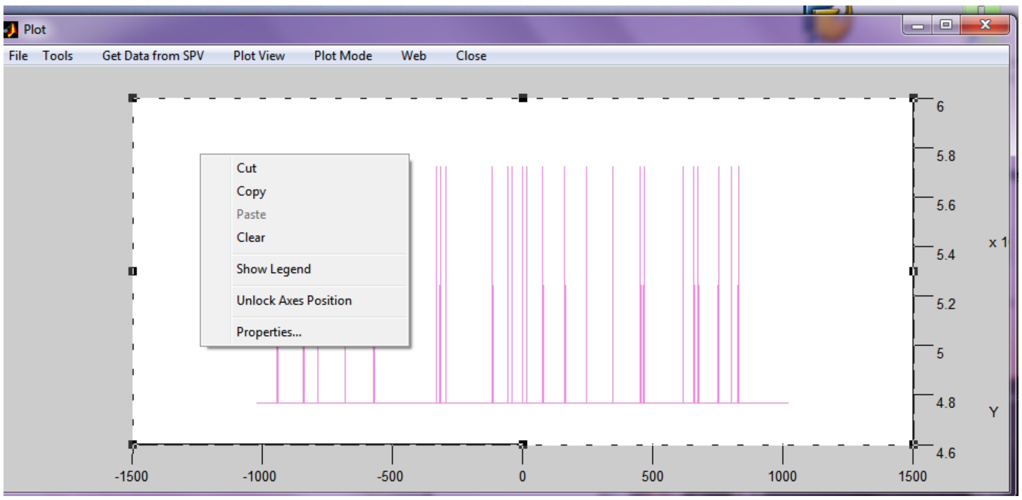

Figure 57: Show Legend

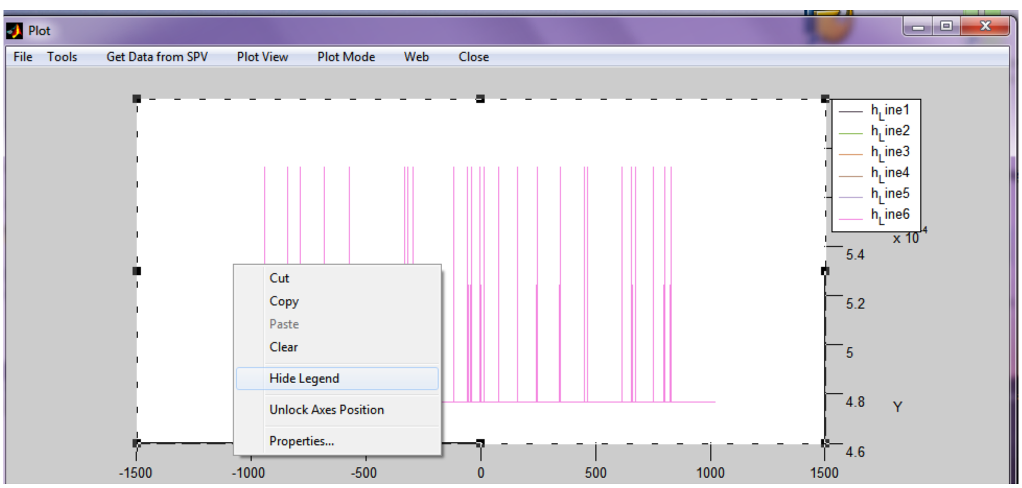

Figure 58: Hide Legend

Right click on the legend text to bring up the following menu selections:

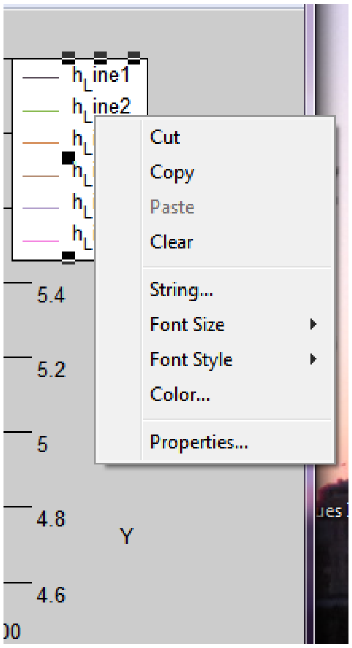

Figure 59: Legend Text Menu

Right click in the legend away from the text to bring up the following menu selections:

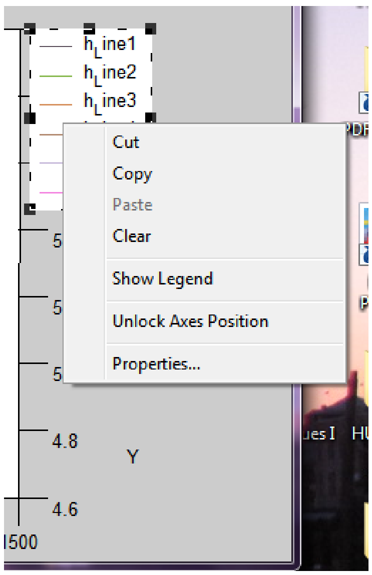

Figure 60: Legend Menu

Select Unlock Axes Position. Move the cursor onto the border of the legend. When it turns into a 4-arrow icon, then you can drag the legend onto the plot. Right click again and choose Lock Axes Position when done to prevent accidental movement.

Clicking on Properties, (either from the legend text or the other part of the legend) brings up the following screens:

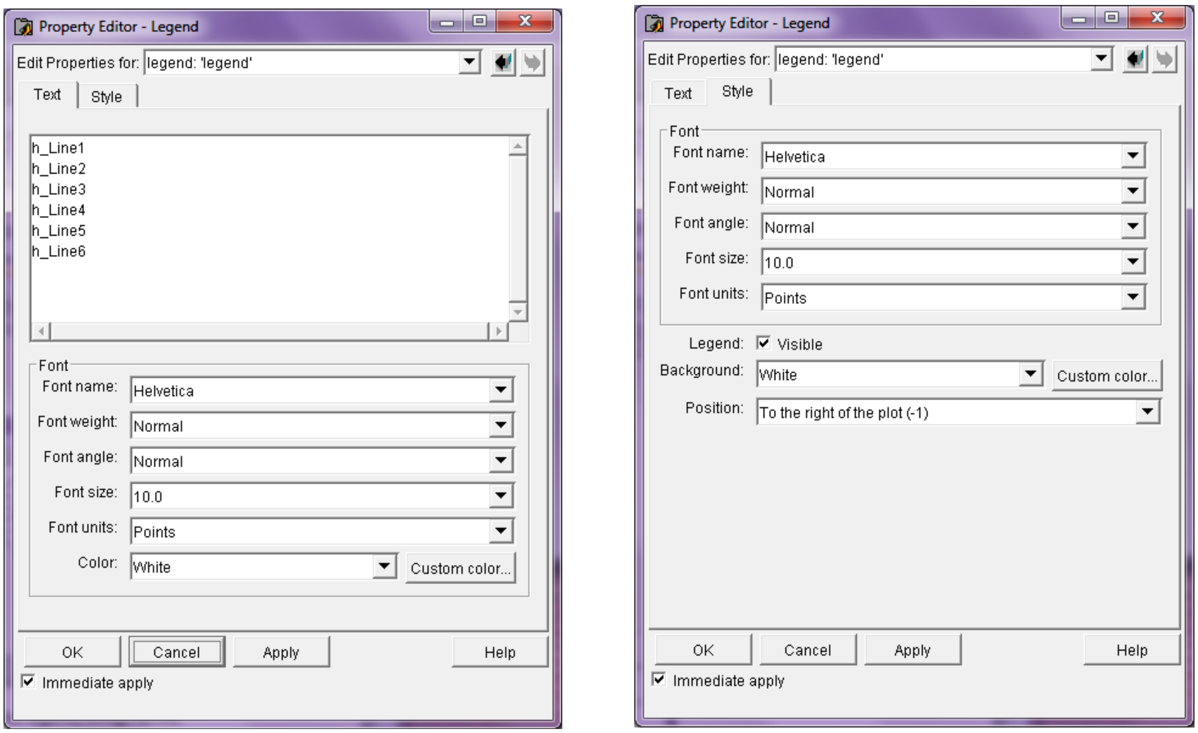

Figure 61: Legend Property Editor

The back and forward buttons in the upper right of the property editor take the user to all the menu choices previously selected for editing (legend, plot exes, etc.). It does not undo or redo the selections that were made.

8.9 ADVANCED PLOT EDITING

Properties can be edited for the figure, legend and axes. To edit the properties of the figure, right click in the plot area. This allows one to choose a background color outside of the plot area or change the title block text, and many other features. Right click on the plot line to edit properties such as color, line weight, etc.

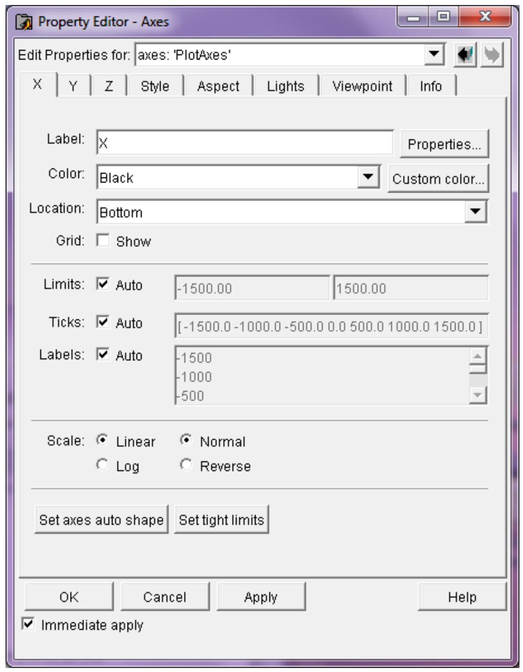

Figure 62: Plot Property Editor

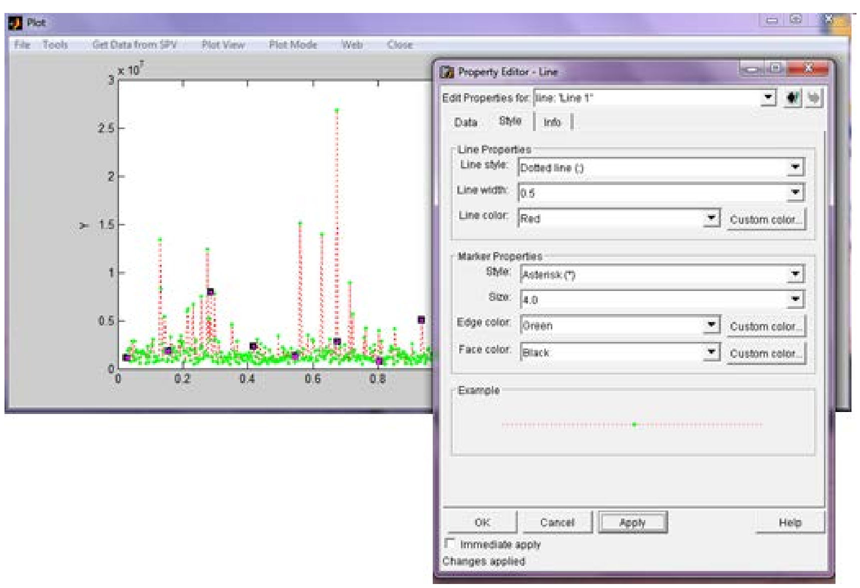

Figure 63: Plot Line Property Editor

9 PURGING THE SCANNER

The MIR8035 Scanner can be purged with dried air or nitrogen to reduce H_2O and CO_2 absorption lines. The Scanner has a 1/8-inch hose barb fitting.

CAUTION:
BEFORE PURGING WITH NITROGEN, ENSURE THAT THERE IS ADEQUATE VENTILATION IN THE ROOM.

Connect the proper tubing to these fittings. We suggest that you use any commercially available two-stage regulator, to regulate the flow of air or nitrogen. Initialize the instrument and begin collecting data. Begin with a steady flow of 1 l/min of dried air or nitrogen, and observe the spectrum. Note that the nitrogen will escape through the power supply enclosure.

After a few minutes, the H_2O and CO_2 absorption bands should disappear. Reduce the air or nitrogen flow to the level required to maintain the spectrum free of H_2O and CO_2 lines.

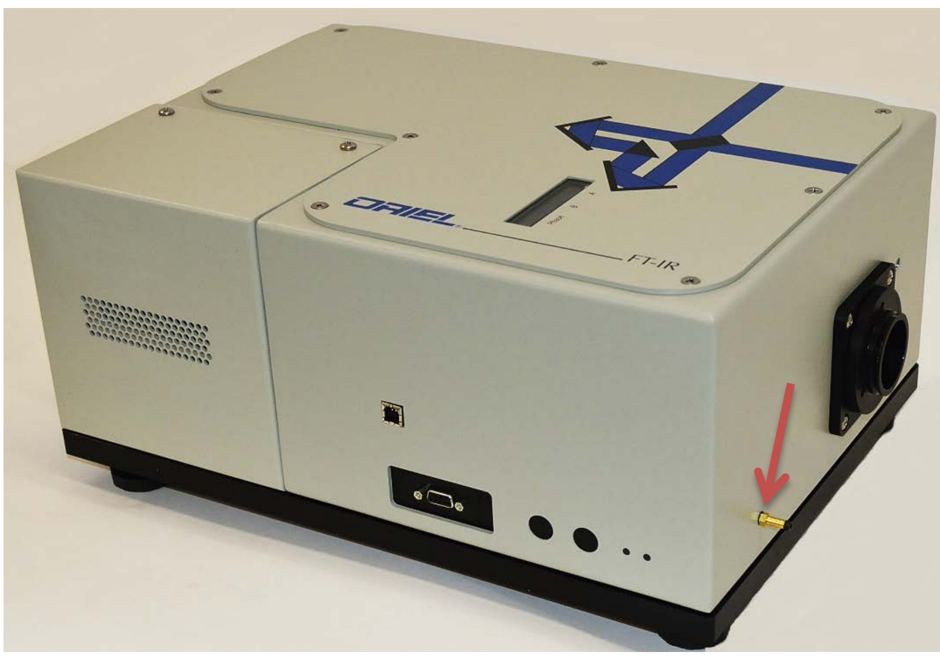

Figure 64: Purge Hose Connector

10 DETECTION SYSTEMS

Make all electrical connections prior to powering up the Scanner.

If using a detector which requires liquid nitrogen, ensure the Dewar is filled before operating. Thermoelectric coolers come with a controller which indicates when the detector has reached its temperature set point.

Always observe standard laboratory precautions when working with liquid nitrogen.

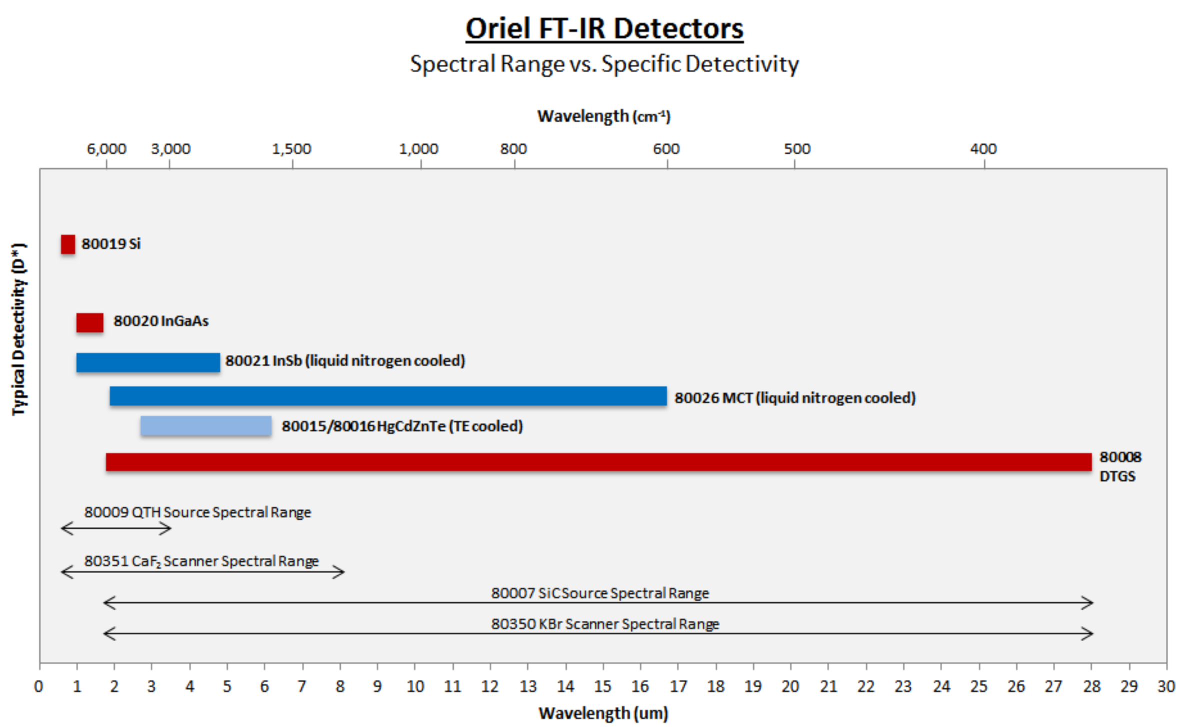

Figure 65: Typical D* Values for FT-IR Detectors

The graph above notes the typical values obtained of the specific detectivity (D*) for various Oriel detectors designed to work with the FT-IR scanner. Typical D* values were obtained with true RMS meter. Blackbody radiation was modulated with a mechanical chopper and the bare detector element was irradiated by a known radiation flux originating from a blackbody at 1273K; no optics were used.

Room temperature detectors are shown in red, TE cooled detectors in light blue and liquid nitrogen cooled detectors in dark blue.

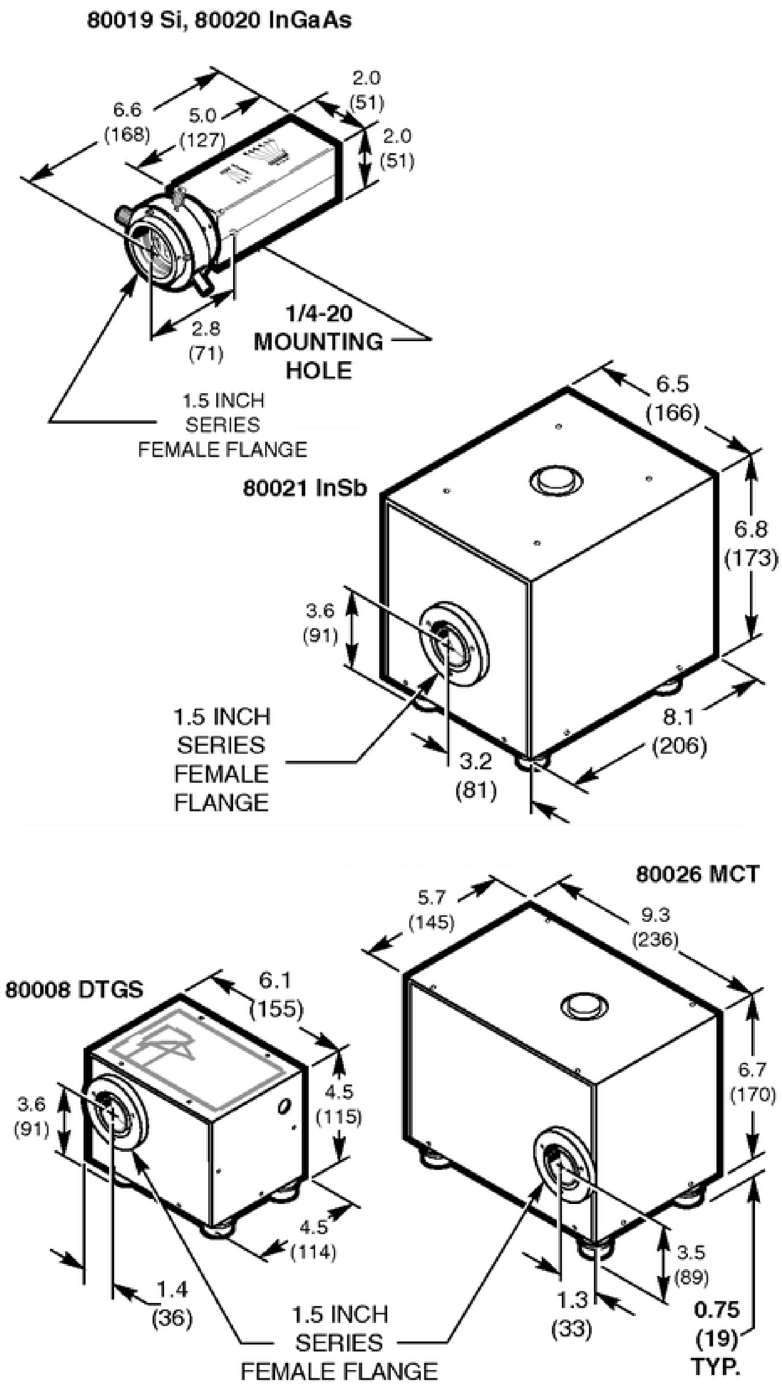

Figure 66: Detector Dimensions

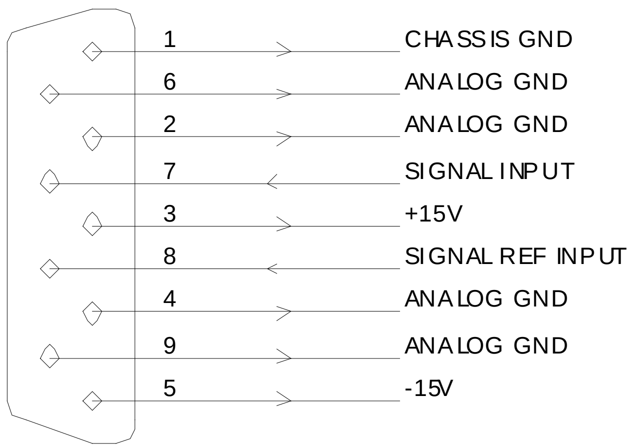

Figure 67: Detector Connector Pinouts

The FT-IR scanner provides power the detector's amplifiers in most cases, so that only one connection cable is required. The TE cooled detectors are powered from their cooler controllers.

For the TE cooled models, connect the cooler controller to the detector and the signal cable from the FT-IR scanner to the detector. Connect the power cord to the TE cooler controller and turn it on.

If it is desired to use a detector not covered in this user's manual, Figure 67 provides the pin assignments for the scanner's D-sub connector.

10.1 Silicon Detector

The 80019 Silicon Detector exhibits excellent stability and sensitivity from 14,000 to 10,000 cm^{-1} (0.7 to 1 μm). This model is a high speed, low noise detector which operates at room temperature; no TE cooling or liquid nitrogen is needed. The detector has a built-in transimpedance amplifier that is powered from the model 80351 Scanner. The amplifier allows gain selections to be made from 10^4 V/A to 10^9 V/A. It also offers three selectable time constant settings, allowing the detector to operate at the lowest possible bandwidth setting for the experiment in order to minimize noise levels. The 80019 includes an aspheric focusing lens with X-Y adjustment and a standard Oriel 1.5-Inch Series female flange. The default factory setting is 10^5 gain and minimum time constant.

10.2 InGaAs Detector

The 80020 InGaAs Detector exhibits excellent stability and sensitivity over its spectral responsivity range. This model is a low noise detector that operates at room temperature; no TE cooling or liquid nitrogen is needed. The detector has a built-in transimpedance amplifier that is powered from the model 80351 Scanner. The amplifier allows gain selections to be made from 10^4 V/A to 10^9 V/A. It also offers three selectable time constant settings, allowing the detector to operate at the lowest possible bandwidth setting for the experiment in order to minimize noise levels. The 80020 includes an aspheric focusing lens with X-Y adjustment and a standard Oriel 1.5-Inch Series female flange. The default factory setting is 10^5 gain and minimum time constant.

Figure 68: 80019 Si and 80020 InGaAs Detectors

10.3 HgCdZnTe Detectors

The 80015 and 80016 Mercury Cadmium Zinc Telluride detector exhibits fast response time, a wide dynamic range and features an integrated preamplifier using a low noise power supply – plus the convenience of thermoelectric cooling. Thermoelectric (TE) cooling reduces noise, increases responsivity and eliminates the inconvenience associated with refilling a liquid nitrogen reservoir. The cooler controller features a temperature lock indicator and provides power to the preamplifier. Monolithic optical immersion of this detector is achieved using a hyperspherical lens shape. The monolithic construction of this detector (the epitaxial layer is grown directly on the lens substrate) is a highly effective technique for making a small detector behave like a larger detector. The active area surface appears to be n2 larger, where n is the index of refraction for the lens. The immersion reduces the image size and increases the detectivity by the same factor. These detectors also includes a CaF_2 focusing lens with X-Y adjustment and an iris that can be manually adjusted from 1 to 25 mm diameter. The iris can act as a Jacquinot Stop. By decreasing the effective source size and reducing the spot size on the detector, it increases the resolution. The iris uses standard Oriel 1.5-Inch Series male and female flanges, allowing it to be easily integrated into the FT-IR system. All necessary cables and a power adapter are included.

Figure 69: 80015/80016 HgCdZnTe Detectors

10.4 DTGS Detector

With its broad spectral response covering the entire range of the 80350 Scanner, the model 80008 Deuterated L-alanine doped Triglycine Sulphate (DTGS) detector is a good choice for many mid-IR applications. There is no need to worry about using liquid nitrogen - this pyroelectric detector operates at room temperature while still achieving good sensitivity. An off-axis parabolic reflector is integrated into the design, rather than a focusing lens. IR refractive optics are expensive and have transmittance limitations. Using this type of reflector provides several advantages. Its gold coating enhances IR reflectance. The focal point is displaced from the mechanical axis, giving full access to the reflector focus area. There is no shadowing with the detector's active area positioned at the focal point. This DTGS detector is optimized for use with the model 80007 silicon carbide IR source. Fine gain adjustments can be made via an internal potentiometer, if desired.

Figure 70: 80008 DTGS Detector

10.5 InSb Detector

The 80021 InSb detector exhibits superior performance over its operating range and approaches the maximum theoretical limit of sensitivity for background-limited applications. This detector requires liquid nitrogen cooling. Liquid nitrogen holding time is eight hours. A preamplifier is integrated into the design, which reduces the effects of background radiation. It is matched with the detector, allowing the detector to function at its ideal operating point. A manually adjustable iris is included with the 80021. Its diameter range is from 0.8" to 1.4" (2 to 36 mm). The iris can act as a Jacquinot Stop. By decreasing the effective source size and reducing the spot size on the detector, resolution is increased. The iris uses standard Oriel 1.5-Inch Series male and female flanges, allowing it to be easily integrated into the FT-IR system.

Figure 71: 80021 InSb Detector

10.6 MCT Detector

The 80026 Mercury Cadmium Telluride (MCT) detector's broad spectral response extends into the mid-IR region. This liquid nitrogen cooled detector measures signals approximately 100 times weaker and acquires data about 8 times faster than Oriel's 80008 room temperature DTGS detector. Liquid nitrogen holding time is eight hours. A two-stage, low noise amplifier is built into the housing and requires no user adjustments. An off-axis parabolic reflector is integrated into the design, rather than a focusing lens. IR refractive optics are expensive and have transmittance limitations. Using this type of reflector provides several advantages. Its gold coating enhances IR reflectance. The focal point is displaced from the mechanical axis, giving full access to the reflector focus area. There is no shadowing with the detector's active area positioned at the focal point. A manually adjustable iris is included with the 80026. Its diameter range is from 0.8" to 1.4" (2 to 36 mm). The iris can act as a Jacquinot Stop. By decreasing the effective source size and reducing the spot size on the detector, the resolution increases. The iris uses standard Oriel 1.5-Inch Series male and female flanges, allowing it to be easily integrated into the FT-IR system.

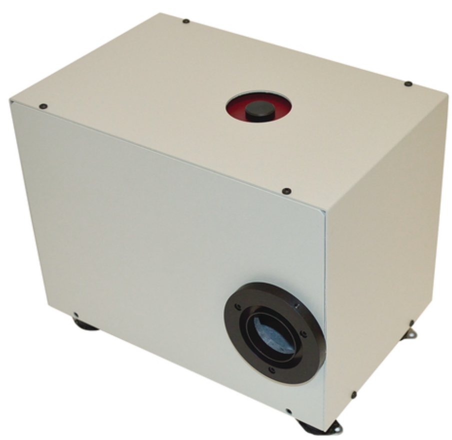

Figure 72: 80026 MCT Detector

11 FT-IR ACCESSORIES

11.1 Fiber Couplers

When transitioning from a collimated beam of light into a fiber (or visa versa), the 80033 is an ideal choice when working in the infrared. An advantage of the 80040 is that it does not require optical alignment. Simply connect the fiber optic cable and it is ready to use. Its 1.5-Inch Series female flange is compatible with the Oriel FT Spectrometer family. An off-axis parabolic reflector is integrated into the design, rather than a condenser lens. IR refractive optics are expensive and have transmittance limitations. Using this type of reflector provides several advantages. Its gold coating enhances IR reflectance. The focal point is displaced from the mechanical axis, giving full access to the reflector focus area. There is no shadowing with the fiber positioned at the focal point. An advantage of the 80033 is that it can accept a variety of fiber terminations. Simply select the appropriate fiber adapter, screw it into place, connect the fiber and adjust its position along the X-Y axis for maximum throughput. Interchangeable fiber adapters are available for SMA, ST and 11 mm ferrule terminations (ordered separately). This type of reflector provides very efficient radiation control because collection or focus occurs over very large solid angles. This makes the 80033 particularly useful with lower power incoherent sources, such as the 80007 Silicon Carbide or 80009 QTH infrared sources.

Figure 73: 80033 Fiber Coupler with 80041 SMA Adapter

Figure 74: 80040 Fiber Coupler

11.2 Accessory Compartment

An exciting variety of FT-IR sample measurement products may be used with the 80070 Accessory Compartment. The 80070 uses Oriel 1.5-inch Series flanges, so it is compatible with Oriel's entire series of FT Spectrometer products. Sampling accessories are positioned at the proper optical height between the Scanner and Detector. Off-axis parabolic reflectors are integrated into the design, rather than lenses. IR refractive optics are expensive and have transmittance limitations. Using this type of reflector provides several advantages. The gold coating enhances IR reflectance. The focal point is displaced from the mechanical axis, giving full access to the reflector focus area. Contact Oriel's technical sales engineers for a list of compatible sampling products.

A 4-inch long spacer tube is provided for connection to the Scanner. This allows for easy access to the hose barb used for nitrogen purging, if desired. Additionally, an extension cable is provided to connect the detector to the Scanner.

Figure 75: 80070 Accessory Compartment

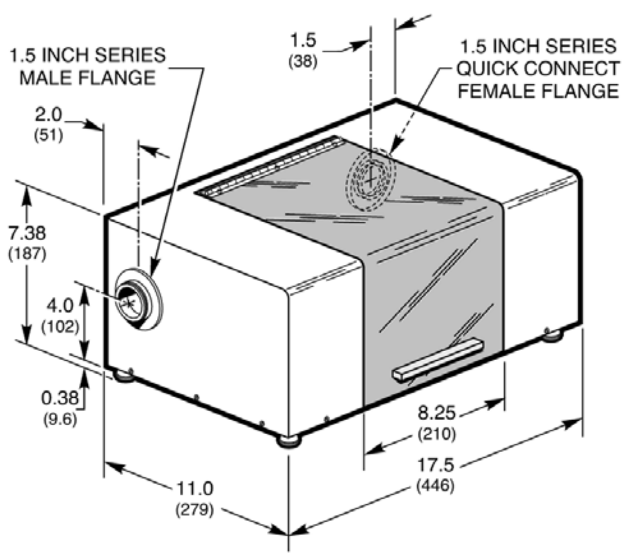

Figure 76: 80070 Accessory Compartment Dimensions

11.3 Off-Axis Parabolic Reflectors

Oriel Instruments offers parabolic reflectors with a gold coating that enhances IR reflectance. Off-axis parabolic reflectors collect radiation from a source at its focal point and reflect it as a collimated beam, parallel to the axis. Alternatively, they can tightly focus a collimated beam at its focus. The focal point is off the mechanical axis, giving full access to the reflector focus area. There are no shadowing problems if a detector, fiber or source is placed at the focus. Off-axis parabolic reflectors provide very efficient radiation control since focus or collection is over very large solid angles. This makes them particularly useful for lower power incoherent light sources. Refer to the Specifications contained in this user's manual for more information.

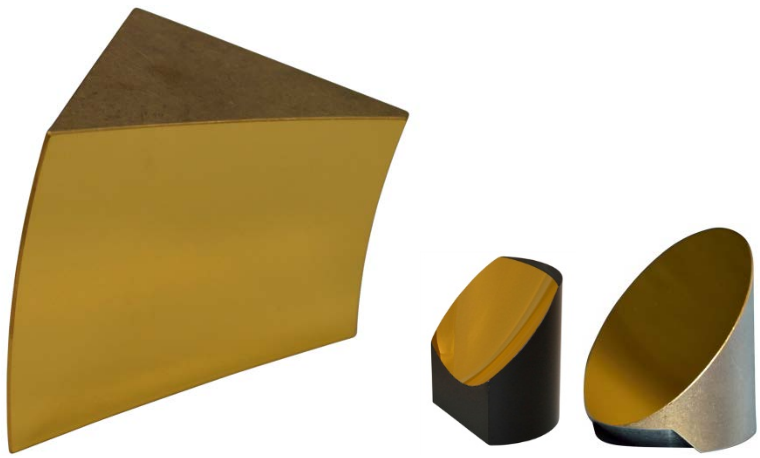

Figure 77: Various Off-Axis Parabolic Reflectors

11.4 Infrared Fiber Optic Cables

Infrared fibers are offered with two types of material. Chalcogenide Glass (CIR) Fibers are used from 2 to 6 um. Polycrystalline (PIR) Fibers function from 4 to 18 um. All fibers are terminated with SMA connectors; for ST or other fiber terminations, contact a Sales Engineer.

The Chalcogenide Fibers are drawn in a core/clad structure, and use a double polymer coating. They are characterized by low optical loss and high flexibility. The jacket material is PVC. Polycrystalline Fibers are extruded from pure AgCL:AgBr solid solution crystals. The core and cladding are the same material with a different ratio of AgCL and AgBr, to create the different index of refraction required to keep the light from leaking through the fiber.

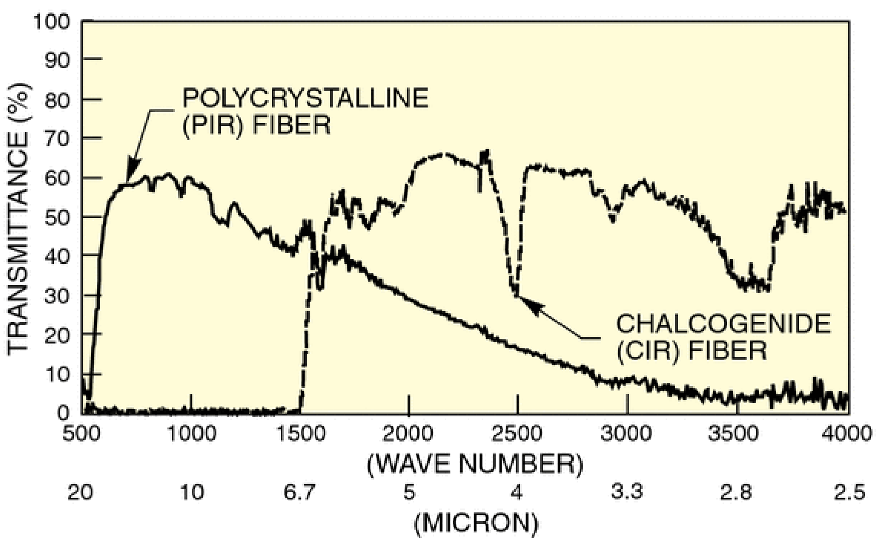

Figure 78: Transmittance of PIR and CIR Fiber Optic Cables

12 INFRARED LIGHT SOURCES

The 80007 is a complete silicon carbide (SiC) infrared light source that provides a smooth continuum from 6,000 to 350 cm-1 (1.7 to 28 µm). The 80009 i quartz tungsten halogen (QTH) infrared light source provides a smooth continuum from 14,000 to 2,800 cm-1 (0.7 to 3.5 µm).

Each model uses a 1.5-Inch Series female output flange which allows the source to be coupled to a variety of items, including Oriel FT Spectrometer products. An off-axis parabolic reflector is integrated into the design, rather than a condenser lens. IR refractive optics are expensive and have transmittance limitations. Using this type of reflector provides several advantages. Its gold coating enhances IR reflectance. The focal point is displaced from the mechanical axis, giving full access to the reflector focus area. Each model produces a 34.5 mm (1.36 inch) diameter collimated output beam with 1° divergence, full angle. A hose fitting is provided to purge the source with nitrogen, if desired.

The 80007 includes a 24-watt SiC emitter and the 80009 includes a 20-watt QTH lamp. Each model includes a stand-alone power supply designed to minimize light ripple. A 1 m (3.3 ft) long cable connects the source to its power supply.

Figure 79: Infrared Light Source and Power Supply

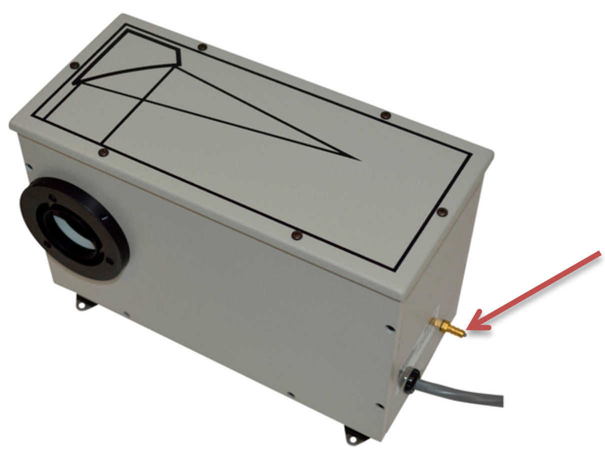

Figure 80: Light Source Hose Barb for N_2 Purge

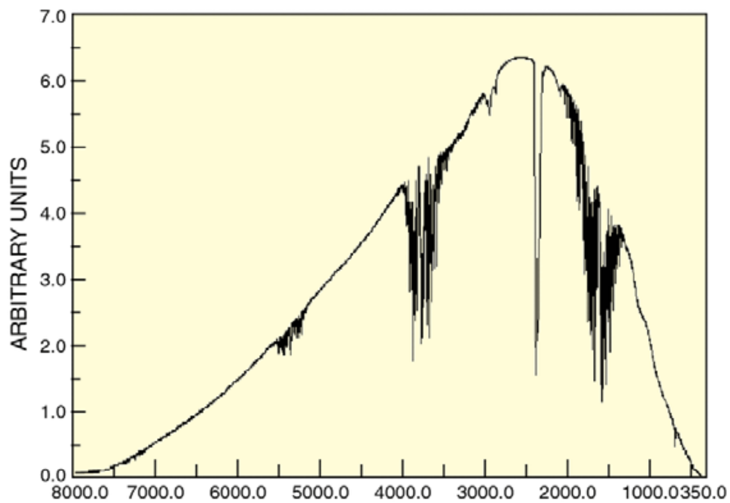

Figure 81: 80007 SiC Spectrum (taken using 80350 Scanner and 80008 DTGS Detector)

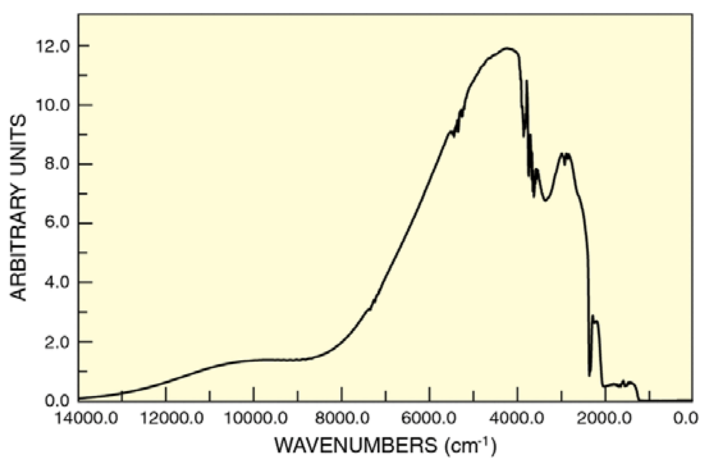

Figure 82: 80009 QTH Spectrum (taken using 80351 Scanner and 80008 DTGS Detector)

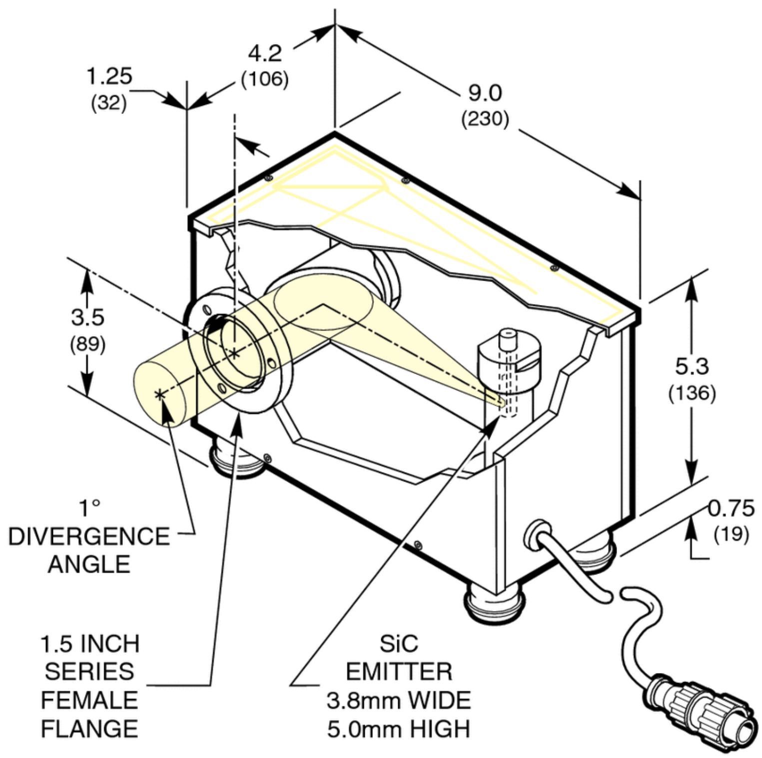

Figure 83: 80007 Light Source Dimensions

12.1 QTH Lamp Replacement

Disconnect the power supply from the light source prior to beginning this procedure. Open the cover of the 80009 QTH IR Light Source using a philips head screwdriver to remove the top cover screws. Grasp the QTH lamp and pull upwards to remove. Replace the lamp by gently pushing it into the socket. Avoid twisting to prevent wearing of the socket. Always wear gloves when handling a lamp. Replace the cover using all screws provided prior to reconnecting the light source to its power supply.

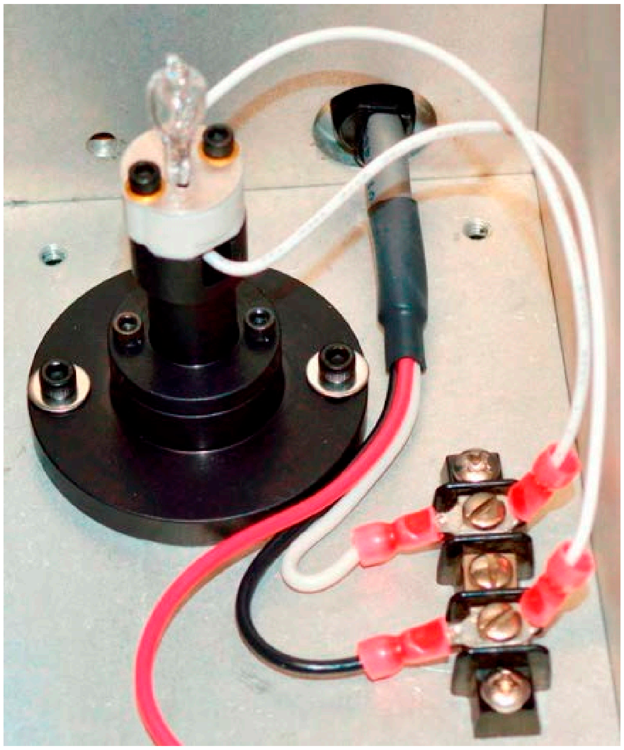

Figure 84: QTH Lamp Replacement

12.2 SiC Emitter Replacement

Disconnect the power supply from the light source prior to beginning this procedure. Open the cover of the 80007 SiC IR Light Source using a philips head screwdriver to remove the top cover screws. Use a wrench to unscrew the brass piece holding the emitter in place. Loosen the screws on the terminal block just enough to remove the wiring leading to the emitter.

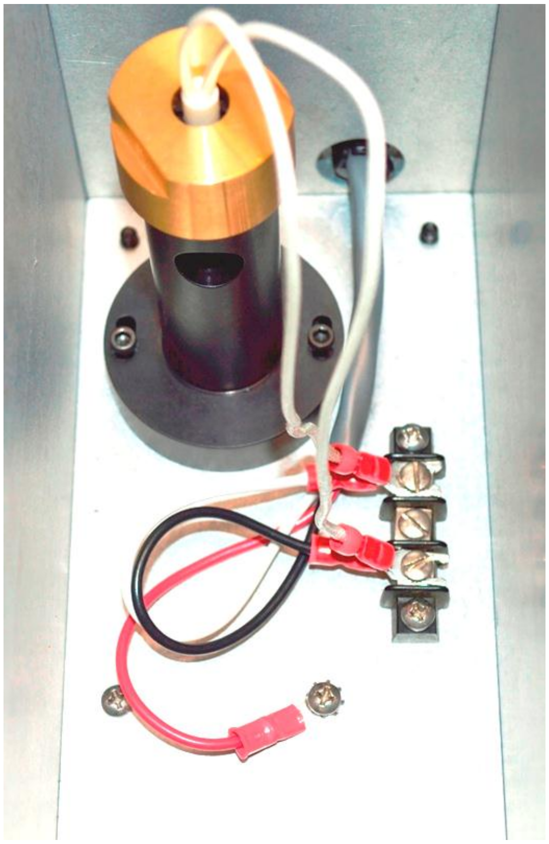

Figure 85: SiC Emitter Replacement

The 80030 replacement SiC Emitter comes with its own wiring, which terminates with lugs. Install the new emitter, ensuring that the radiating area is centered with respect to the opening in the holder. Replace the brass piece and secure the emitter. Connect the lugs to the terminal blocks and tighten the terminal block screws.

Ensure the wiring is not in the path of the light emitted from the holder. Push the wiring to the side, if necessary. Replace the cover using all screws provided prior to reconnecting the light source to its power supply.

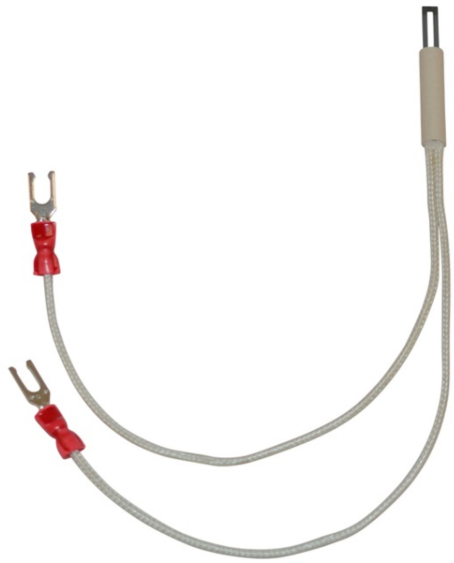

Figure 86: 80030 SiC Emitter

Figure 87: 80030 SiC Emitter Radiating Area

13 PROGRAMMING

13.1 Programming with the MIR™ MIR8035 ActiveX (FTS_AX.OCX)

When the MIR8035 ActiveX and Drivers CD setup is run, the **FTS_AX** Control is installed and is registered along with the MIR8035 instrument USB2.0 drivers.

13.1.1 MIR8035 ActiveX Methods:

The Properties menu can be brought up by right clicking on the ActiveX container for the FTS_AX.

BOOL Acquire(void)

Acquires an interferogram from the MIR8035, (see also GetDataDblArray)

Returns FALSE if triggering an acquisition on the MIR8035 has failed

Note: If the ZPD Adjust is checked on the property page, a ZPD adjust will be performed with the Acquire. The adjusted interferogram will be read on the next Acquire.

VARIANT GetDataDblArray(void)

returns a variant pointing to array of the last Acquired data *(volts)*

Cast the returned variant to an array of doubles

(See RawDataBuffer and NumberPoints properties section for environments that do not support passing of VARIANT type)

void SetEncoderMode(ULONG state)

state = 1: the encoder is enabled for slider control, laser not used, for use when laser has failed or the instrument has been jostled out of alignment.

state = 0: the encoder is disabled. The laser is used for slider control, normal operation mode for acquiring interferogram data.

Note: The MIR8035 powers up with the encoder enabled, this is so incase the laser is not functioning or misaligned the slider motion is still functioning which allows the lack of laser signal to be troubleshot without computer connection.

The first thing any application should do is disable encoder mode.

void DoAutoAdjustZPD(void)

Performs an acquisition and automatically adjusts the zero position to for the centerburst.

NOTE: *a subsequent Acquire will obtain the zero adjusted interferogram*.

void SendZPD(long zpdoffset)

Moves the centerburst by the number of points specified by zpdoffset.

long zpdoffset: - value moves the centerburst to the right

+ value moves the centerburst to the left

ULONG GetLaserSignalA(void)

Returns the % level of laser signal A, corresponds to the first (left) % number on the MIR8035 LCD panel.

ULONG GetLaserSignalB(void)

Returns the percentage level of laser signal B, corresponds to the second percentage value on the MIR8035 LCD panel.

ULONG GetPhase(void)

Returns the phase degrees, corresponds to the rightmost number on the MIR8035 LCD panel.

13.2 MIR8035 ActiveX Properties:

The RawDataBuffer and NumberPoints public properties are made available for applications like MATLab that do not support VARIANTs. Programming environments like LabView, which support VARIANTS, should use the VARIANT GetDataDblArray(void) method shown above.

long RawDataBuffer:

pointer to the address in memory of an array of doubles containing the interferogram data array. *(volts)*

long NumberPoints:

the number of data points in the interferogram array

14 TROUBLESHOOTING

Set the scanner to encoder mode when troubleshooting. Refer to Section 7.4.1.

14.1 Beamsplitter Alignment

Problem: Scanner does not scan

Solution: The MIR8035™ is a very sensitive instrument; if the instrument is inadvertently misaligned, it will not scan.

Turn off power to the Scanner. Insert a flat blade screwdriver into the beamsplitter adjustment access ports.

Once the screwdriver's slot is engaged, very slowly turn the screwdriver while observing the percentage values on the LCD. Turn the tool first in one, then the other direction to determine which way increases the percentage values.

Repeat with the second access port. Continue this process until the signal is maximized. The instrument should now be scanning. Slowly remove the tool, taking care not to accidentally disturb the beam splitter position.

Allow the instrument to scan for at least one hour to allow all opto-mechanical parts to warm up.

14.2 Phase Adjustment

Problem: Phase value on LCD is not within an acceptable value

Solution: Open the scanner unit and slowly turn the phase wheel until the value is correct.

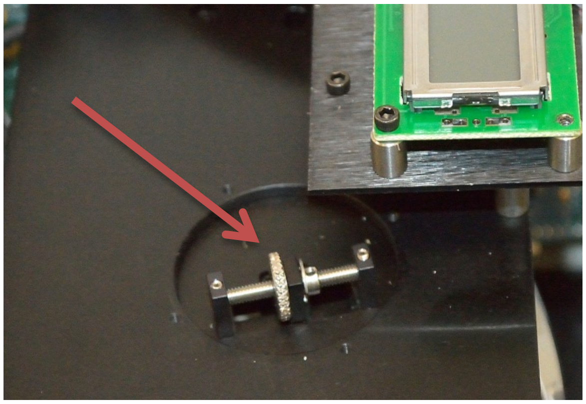

Figure 88: Phase Adjustment wheel

14.3 ZPD Optical Sensor Realignment

Problem: You cannot get an interferogram even though the Scanner is scanning and the LCD display shows plenty of signals. Or, the interferogram cannot be centered at Zero. (See Figure 89)

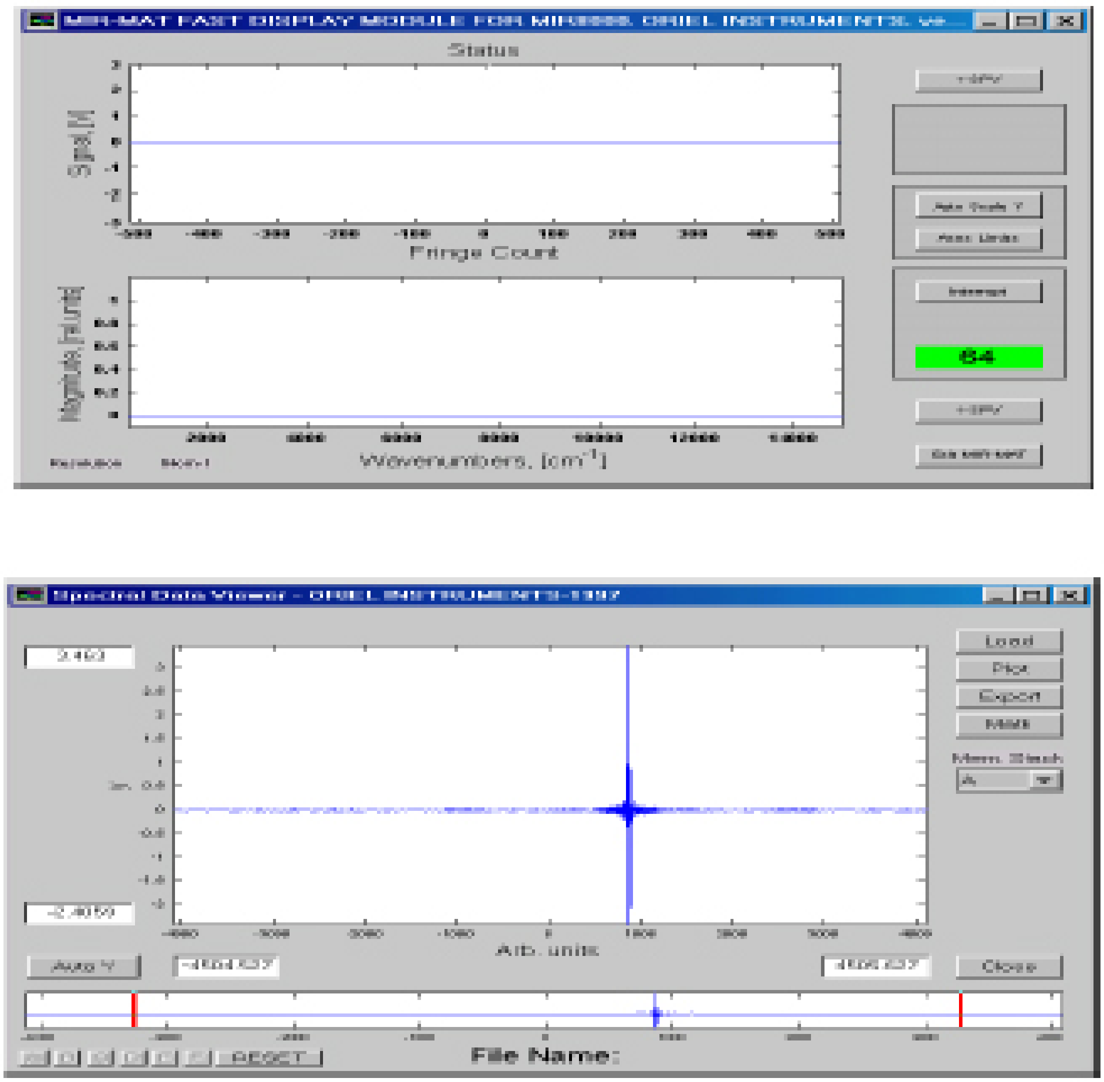

Figure 89: Centerburst cannot be centered at zero

Solution: During transportation or beam splitter interchange, the optical sensor, which senses ZPD, has been misaligned.

1. With the instrument on and scanning, set the resolution to 4 cm^{-1}; if the centerburst is still not visible in the Display Screen, change the resolution to 1 cm^{-1}.

2. Once the centerburst is visible, although off center, turn off power to the Scanner and remove the cover.

3. With the provided #3-32 wrench, loosen the vertical screw on the optical flag by turning it 1/8 of a turn counterclockwise, as shown in Figure 90.

4. Turn horizontal screw 1/4 turn clockwise (which moves the centerburst in the positive direction) or counterclockwise (which moves it in the negative direction).

5. Turn Scanner on, set the resolution to 4 cm^{-1}, and begin acquiring data. The centerburst should now be visible. The amount and direction of movement will determine what further adjustments must be made. Repeat step 4 as many times as necessary to bring the centerburst to zero.

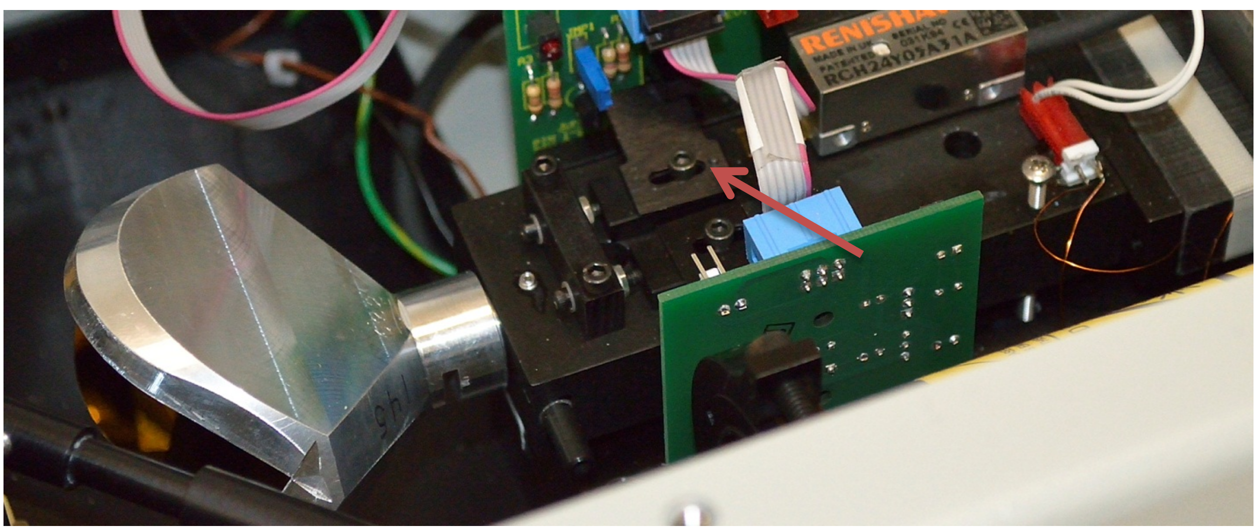

Figure 90: Opto Flag for ZPD Adjustment

14.4 Gain Control Adjustment

Problem: You hear a high pitch sound when scanning

Solution: Remove the cover from the Scanner. Adjust the Gain Control (see Figure 91) until the high pitch sound disappears. Replace the cover, turn the Scanner off, and then back on again; the instrument should now be running smoothly.

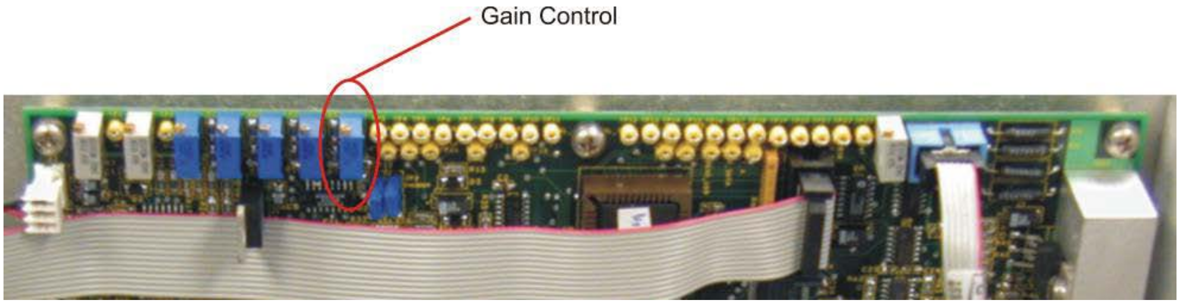

Figure 91: Adjust the Gain Control with a screwdriver.

14.5 ZPD Adjustment

To perform a ZPD Adjust:

1. Click “stop” on the main MIRMAT™ screen drop down
2. Bring up the Properties menu
3. Select a Resolution value of 16 or less. Leave ZPD Adjust unchecked, then click OK.
4. Click “single” on MIRMAT™ main screen to acquire a scan and observe that interferogram is valid. See Calibration and Troubleshooting section if there is no centerburst.
5. Click “stop” on the main MIRMAT™ screen
6. Bring up the Properties dialog
7. Check the ZPD Adjust Box and click OK. The resolution must be set to 16 or less when the ZPD Adjustment is enabled.
8. On the main MIRMAT™ screen click single to Acquire a scan, the instrument will adjust the interferogram after this scan

On the main MIRMAT™ screen click single to Acquire a scan, you should observe that the interferogram centerburst is now centered.

The first subsequent acquire performs a ZPD adjustment, the next acquire will show the adjusted interferogram.

15 LASER SAFETY INTERLOCK SWITCH

The Laser Interlock Switch turns off the Laser when the Instruments cover is removed. The switch is designed to be defeated, allowing a qualified service person to apply power to the Laser. In order to disable the interlock, the switch needs to be up.

CAUTION: Direct eye exposure to the laser beam must be avoided. Laser safety glasses are strongly recommended any time the power is applied to the Laser and the instrument is open.

Protective eyewear worn must be appropriate for use with HeNe lasers. Newport includes one set of safety glasses with the alignment packaged that is shipped with every instrument.

Figure 93 shows the interlock switch with the cover removed. The illustration on the left shows the normal switch position with the Laser shut off when the cover is removed. The illustration on the right (with the plunger lifted up) would allow the power to be applied to the laser. When the Laser is on with the interlock defeated, the LED mounted next to the switch will light.

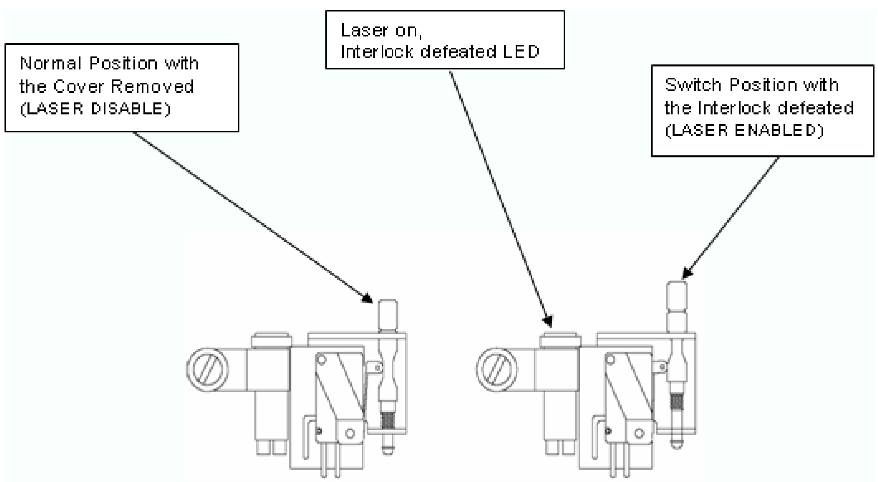

Figure 92: Interlock Function

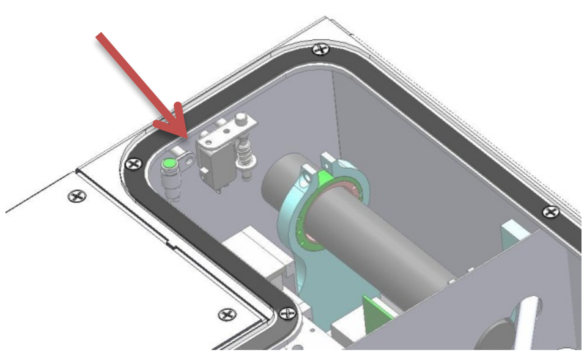

Figure 93: Interlock Location

16 WINDOW REPLACEMENT

When the scanner is used in the low humidity environment specified, there is no need to replace the input and output windows unless it is desired to change from a KBr to CAFl2 model – or visa versa. If that is the case, the beamsplitter must also be changed to the desired material. Windows can be replaced in the field. However, beam splitter replacement is best performed by qualified service personnel.

Always wear latex gloves to avoid damaging the optics.

1. Mark the top of the "window ring" with a pencil so you can later distinguish the top from the bottom, as shown in Figure 94.
2. Remove the two lower screws first, then the top, while holding the ring.
3. Located behind the ring is a gasket; this gasket may stick to either the ring or the window upon removal. If it sticks to the window, you need to remove it and put it back into the groove of the ring.
4. Pick the window out of the instruments housing carefully and by its sides only. Do not touch the window with your gloved fingers.
5. Insert the new window, again, handling it by its sides only.
6. Place the ring back into position, pencil mark up.
7. Line up the screw holes, and screw back into place. The ring should be seated tightly against the wall of the housing.

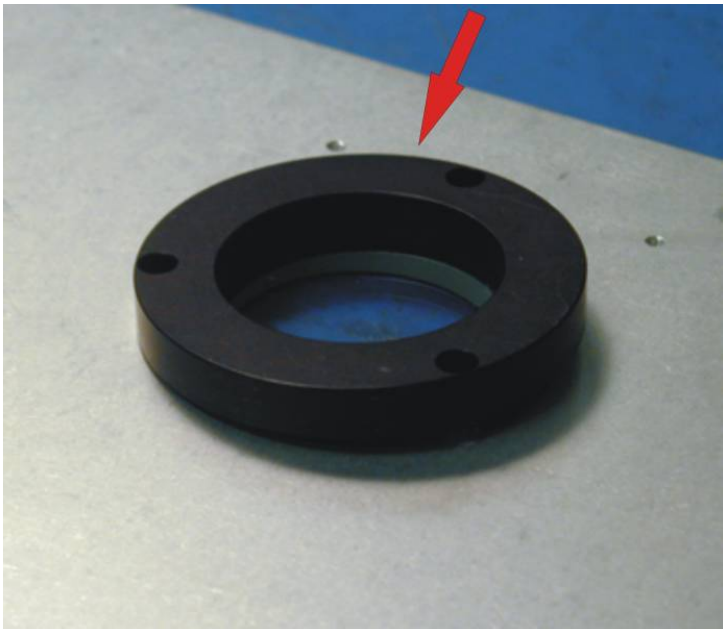

Figure 94: Marking the top of the window ring

17 SPECIFICATIONS

Scanner

Parameter	80350SP01	80351SP01
Function	Spectral Analyzer	
Configuration	Main unit is an enclosed and purgeable chamber, containing an interferometric modulator	
Interferometer	90° Michelson interferometer with corner cube reflectors and retroprism	
Input Maximum Divergence Angle	1° full angle	
Beam Splitter	KBr	CaF_2
Input/Output Windows	KBr	CaF_2
Spectral Range	6,000 to 350 cm^{-1} [1.7 to 28 um]	14,000 to 1,200 cm^{-1} [0.7* to 8.3 um]
Aperture	1.5 inch [38 mm]	
Throughput	7×10^{-3} cm^2 Sr for acceptance angle corresponding to 1 cm^{-1} resolution	
Resolution	Selectable from 0.5 to 64 cm^{-1} in 8 steps; corresponds to .02 nm at 700 nm at .04 um at 28 um	
Scanning Mirror Speed at 40 kHz	6.33 mm/second (at laser modulation frequency)	
Scanning Mirror Speed at 25 kHz	3.956 mm/second (at laser modulation frequency)	
Scanning Mirror Speed at 15 kHz	2.373 mm/second (at laser modulation frequency)	
Scanning Mirror Speed at 5 kHz	0.791 mm/second (at laser modulation frequency)	
HeNe Laser Phase Tolerance	90° ± 3°	
Reference Signal	Two HeNe laser sinusoidal interferograms in-quadrature for scanner control and data acquisition	
ZPD Point	Scanning mirror can be finely adjusted by the software to get ZPD point exactly in the middle of a scan; this position will be maintained with zero error as long as the unit is powered up	
Interferogram	Double sided	
Oversampling	1x, 2x or 4x	
Wave Number Accuracy	0.01 cm^{-1}	
Wave Number Resolution	0.5 cm^{-1}	
Signal to Noise Ratio	1000:1 at 2500 cm^{-1}, 4 cm^{-1} resolution, 1 scan sample/1 scan reference using DTGS detector	
Optical Axis Height	2.88 inch [73.1 mm] (from bottom of base plate to center of aperture)	

* Oversampling must be set to 4x. Without oversampling, the spectral range lower limit is 1.4 um.

General

Parameter	80350SP01	80351SP01
Dimensions, Scanner	15.6 x 11.75 x 8.0 inch [419 x 300 x 203 mm]	
Weight, Scanner	36.9 lb [16.7 kg]	
AC Requirements, Scanner	84 to 264 VAC, 47 to 63 Hz	
Operating Temperature Range	15°C to 40°C	
Storage Temperature Range	0°C to 50°C	
Relative Humidity (Operation or Storage)	Cannot exceed 30%	
Coupling	1.5 inch series Oriel male flanges	

Data Acquisition

Parameter	80350SP01	80351SP01
Computer Interface	USB 2.0	
Hardware, Internal	16 bit A/D converter with 250 kHz throughput	
Sample Frequency	160 kHz to 20 kHz with 4x oversampling 40 kHz to 5 kHz with no oversampling	
Filters	93 Hz low pass filter (5 kHz) 80 kHz high pass filter (40 kHz)	
Software	MIRMat™	
Selectable Units	µm, nm, cm^{-1}, MHz, eV, kcal/mol, kJ/mol, K	
Data Presentation Type	Interferogram, single beam, transmittance	

Software

Parameter	80350SP01	80351SP01
Scan Parameter Settings	Velocity, resolution, oversampling on/off, bidirectional data acquisition on/off	
Scanner Calibration	Fine adjustment of ZPD and delay of A/D converter triggering signals	
FFT Parameter Settings	Type of apodization, zero fill, parameters for phase correction and scaling	
Calculations	Addition, subtraction, multiplication, division, Log_{10}, Square Root, Invert, Negate, Absolute	
Data File Formats	ASCII, .mat, .fig	
Software Development	Microsoft® Active X control allows applications to be built using Visual Basic, Visual C++, MATLAB®, LabVIEW® or other Microsoft applications compatible with Active X technology	

Detectors, Room Temperature

Parameter	80008	80019	80020
Type	DTGS	Si	InGaAs
Cooling	n/a	n/a	n/a
Responsivity Range	6,000 to 350 cm^{-1} [1.7 to 28 um]	14,000 to 10,000 cm^{-1} [0.7 to 1 um]	10,000 to 6,000 cm^{-1} [1 to 1.7 um]
Detector Element Size	1.3 mm diameter	0.2 mm diameter	1 mm diameter
Window Material	KBr	BK7	BK7
Preferred Beam Splitter	KBr	CaF_2	CaF_2
Optics	Gold coated off-axis parabolic reflector	Pyrex Aspheric Focusing Lens	Pyrex Aspheric Focusing Lens
X-Y Adjust, Optics	n/a	Yes	Yes
Typical D*	1.5×10^{9} cm $Hz^{1/2}W^{-1}$	1×10^{14} cm $Hz^{1/2}W^{-1}$	1×10^{12} cm $Hz^{1/2}W^{-1}$
Operating Bandwidth (with amplifier)	100 Hz to 40 kHz	100 Hz to 40 kHz (gain dependent)	100 Hz to 40 kHz (gain dependent)
Gain, Adjustable	Potentiometer	10^{4} to 10^{9} V/A	10^{4} to 10^{9} V/A

Detectors, Thermoelectrically Cooled

Parameter	80015	80016
Type	HgCdZnTe	
Cooling	TE Cooled	
Responsivity Range	3,550 to 1,540 cm-1 [2.8 to 6.5 um]	
Detector Element Size	1 x 1 mm	
Window Material	CaF_2	
Preferred Beam Splitter	CaF_2	
Typical D*	1.2×10^{10} cm $Hz^{1/2}W^{-1}$	
Operating Bandwidth (with amplifier)	10 Hz to 140 kHz	
Optics	CaF_2 Focusing Lens	
X-Y Adjust, Optics	Yes	
Iris, Manual Adjust	2 to 36 mm diameter	
Input Voltage	100 to 130 VAC, 50 to 60 Hz	200 to 240 VAC, 50 to 60 Hz

Detectors, Liquid Nitrogen Cooled

Parameter	80021	80026
Type	InSb	MCT
Cooling	Liquid Nitrogen	Liquid Nitrogen
Responsivity Range	10,000 to 2,000 cm^{-1} [1 to 5 um]	5,000 to 600 cm^{-1} [2 to 17 um]
Detector Element Size	1 x 1 mm	1 x 1 mm
Window Material	Sapphire	ZnSe
Preferred Beam Splitter	CaF_2	KBr
Typical D*	1×10^{11} cm $Hz^{1/2}W^{-1}$	5×10^{10} cm $Hz^{1/2}W^{-1}$
Operating Bandwidth (with amplifier)	100 Hz to 40 kHz	100 Hz to 40 kHz
Optics	CaF_2 Focusing Lens	CaF_2 Focusing Lens
X-Y Adjust, Optics	n/a	n/a
Iris, Manual Adjust	2 to 36 mm diameter	1 to 25 mm diameter

Infrared Light Sources

Parameter	80007	80009
Type	Silicon Carbide	Quartz Tungsten Halogen
Power	24 W	20 W
Spectral Range	6,000 to 350 cm^{-1} [1.7 to 28 um]	14,000 to 2,800 cm^{-1} [0.7 to 3.5 um]
Collimated Beam Diameter	1.36 inch [34.5 mm]	1.36 inch [34.5 mm]
Light Ripple, Peak to Peak	0.10%	0.10%
Optics	Gold coated off-axis parabolic reflector	Gold coated off-axis parabolic reflector
AC Requirements	85 to 264 VAC, 47 to 63 Hz	85 to 264 VAC, 47 to 63 Hz

Fiber Couplers (Optional)

Parameter	80033	80040
Fiber Optic Cable Connection Type(s)	Universal * (SMA, ST, 11mm ferrule)	SMA
Optics	Gold coated off-axis parabolic reflector	Gold coated off-axis parabolic reflector
X-Y Adjust	No	Yes

*80033 requires fiber connection adapter (ordered separately)

80033 Fiber Coupler Adapters (Optional)

Model	Type
80041	SMA
80042	ST
80043	11 mm ferrule

Accessory Compartment (Optional)

Parameter	80070
Coupling	1.5 inch series flange
Optics	Gold coated reflectors

Off-Axis Parabolic Reflectors (Optional)

Parameter	80120	80121	80122
Coating	Gold	Gold	Gold
Effective Focal Length	5.5 inch [139.7 mm]	7.28 inch [185.0 mm]	0.8 inch [20.3 mm]

Infrared Fiber Optic Cables (Optional)

Model	Material	Transmittance Range	Core Diameter	Length
80060	Chalcogenide Glass (CIR)	5,000 to 1,666 cm^{-1} [2 to 6 um]	.034 inch [860 um]	5 ft [1.5 m]
76905	Chalcogenide Glass (CIR)	5,000 to 1,666 cm^{-1} [2 to 6 um]	.010 inch [250 um]	3 ft [1.0 m]
76906	Chalcogenide Glass (CIR)	5,000 to 1,666 cm^{-1} [2 to 6 um]	.016 inch [400 um]	3 ft [1.0 m]
76907	Chalcogenide Glass (CIR)	5,000 to 1,666 cm^{-1} [2 to 6 um]	.020 inch [500 um]	3 ft [1.0 m]
76908	Polycrystalline (PIR)	2,500 to 556 cm^{-1} [4 to 18 um]	.016 inch [400 um]	3 ft [1.0 m]
76909	Polycrystalline (PIR)	2,500 to 556 cm^{-1} [4 to 18 um]	.025 inch [630 um]	3 ft [1.0 m]
76910	Polycrystalline (PIR)	2,500 to 556 cm^{-1} [4 to 18 um]	.035 inch [900 um]	3 ft [1.0 m]

Note: All fibers listed above are terminated with SMA connections.

18 REPLACEMENT PARTS

If there is a need to purchase a replacement shipping container, beam splitter alignment tool(s), laser alignment kit or other items not listed below, please contact Oriel Instruments or local sales representative.

Please note that if it is desired to refit the scanner from KBr to CaF2 (or visa versa), both the beam splitter and windows must be replaced.

Replacement Parts

Model	Description
80004	Beamsplitter, KBr
80005	Beamsplitter, CaF_2
80010	Windows, KBr (set of 2 with gaskets)
80011	Windows, CaF_2 (set of 2 with gaskets)
80030	SiC Emitter, 24 W
6319	QTH Lamp, 20 W

19 DECLARATION OF CONFORMITY

EC DECLARATION OF CONFORMITY

Manufacturer's name:	Newport Corporation
Manufacturer's address:	150 Long Beach Boulevard Stratford, CT 06615 USA
Declares that the product:	
Product Name:	ORIEL® FT-IR Spectrometers
Model Numbers:	80350SP01, 80351SP01
Type of equipment:	Electrical equipment for measurement, control and laboratory use in industrial locations
conforms to the following Product Specifications:	
Safety:	EN 61010-1:2010
EMC:	EN 61326-1:2006+cor:2008+cor:2010
complies with the following Directives:	
	2004/108/EC EMC Directive 2006/95/EC Low Voltage Directive
and accordingly, carries the mark mark affixed:	Beaune; May 19, 2011
Domenic Assalone	Bruno Rety Authorized to compile technical documentation
Site Manager, Oriel Products Division	Group Director, PPT Instrument and Motion Europe
150 Long Beach Boulevard	Micro-Controle Division of Newport Corporation
Stratford, CT 06615 USA	Zone Industrielle
	45340 Beaune la Rolande, France

20 Appendix A: FT-IR Technical Discussion

20.1 Why is There a Shorter Wavelength Limit for FT-IR Spectral Analyzers?

To figure this out let us assume that we are using a collimated monochromatic light source, with the FT-IR spectrometer. This light will produce an interferogram in the form of a sinusoid at the detector. Our goal is to find the spectrum - in this case to determine the wavelength of the incoming radiation. We know that when the light intensity goes from one maximum of the interferogram to the next maximum, the optical path difference between the two legs of the interferometer changes by exactly 1 wavelength of the incoming radiation.

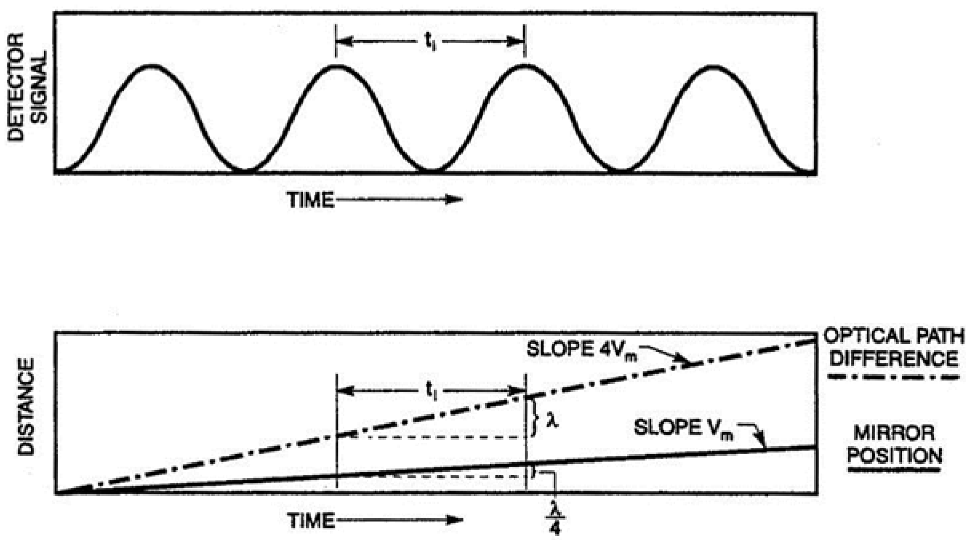

Figure 95: Detector signal vs. time; mirror position and OPD vs. time

With this in mind we can measure the frequency f_i or period $t_i = 1/f_i$ of the interferogram with, say, an oscilloscope. Then we can find the wavelength through the formula:

$$\lambda_i = V_0 * t_i = V_0 / f_i$$

Equation 1

Where:
$V_0 =$ the speed of change of the optical path difference

V_0 is directly related to the speed of the scanning mirror. For MIR8035™, V_o is exactly four times the speed of the scanning mirror: $V_0 = 4V_m$.

There is, however, an important practical difficulty. We need to maintain the velocity V_m constant at all time, and we need to know what this velocity is, with a high degree of accuracy. An error in the velocity value will shift the wavelength scale. Fluctuations in V_m have a different effect; they manifest themselves as deviations of the interferogram from a pure sine wave that in turn will be considered as a mix of sinusoids. In other words, we will think that there is more than one wavelength in the incoming radiation. This behavior produces what are called "spectral artifacts".

Since the manufacture of an interferometrically accurate drive is extremely expensive, FT-IR designers added an internal reference source into the interferometer to solve the drive performance problem. A HeNe laser emits light with a wavelength which is known with a very high degree of accuracy and which does not significantly change under any circumstance. The laser beam takes the same path through the interferometer and produces its own interferogram at a separate detector. This is essentially used as an extremely accurate measure of the interferometer (optical path difference).

For this interferogram we can write an equation similar to Equation 1

$$\lambda = V_0 * t_r = V_0 / f_r$$

Equation 2

And combining Equation 1 and Equation 2 together:

$$\lambda_i = \lambda_r * (f_r / f_i)$$

Equation 3

Thus, V_m has dropped out of the picture and we can calculate the spectrum without knowledge of the velocity or without extremely tight tolerances on the velocity.

This was just a theoretical example. Now let us see how the reference interferogram is actually used in the MIR8035™. The signal from the interfering beams of the HeNe are monitored by a detector. What is observed is a sinusoidal signal. The average value is the same as you would see if the beam was not divided and interference produced. The sinusoid goes positive and negative about this value, so the average signal level is called the zero level. A high precision electronic circuit produces a voltage pulse when the signal reference sinusoid crosses the zero level. By use of only positive zero crossings, the circuitry can develop one pulse per cycle of the reference interferogram, or use all zero crossings for two pulses per cycle of this interferogram. The latter case is called oversampling. These pulses trigger the A/D converter which immediately samples the main interferogram.

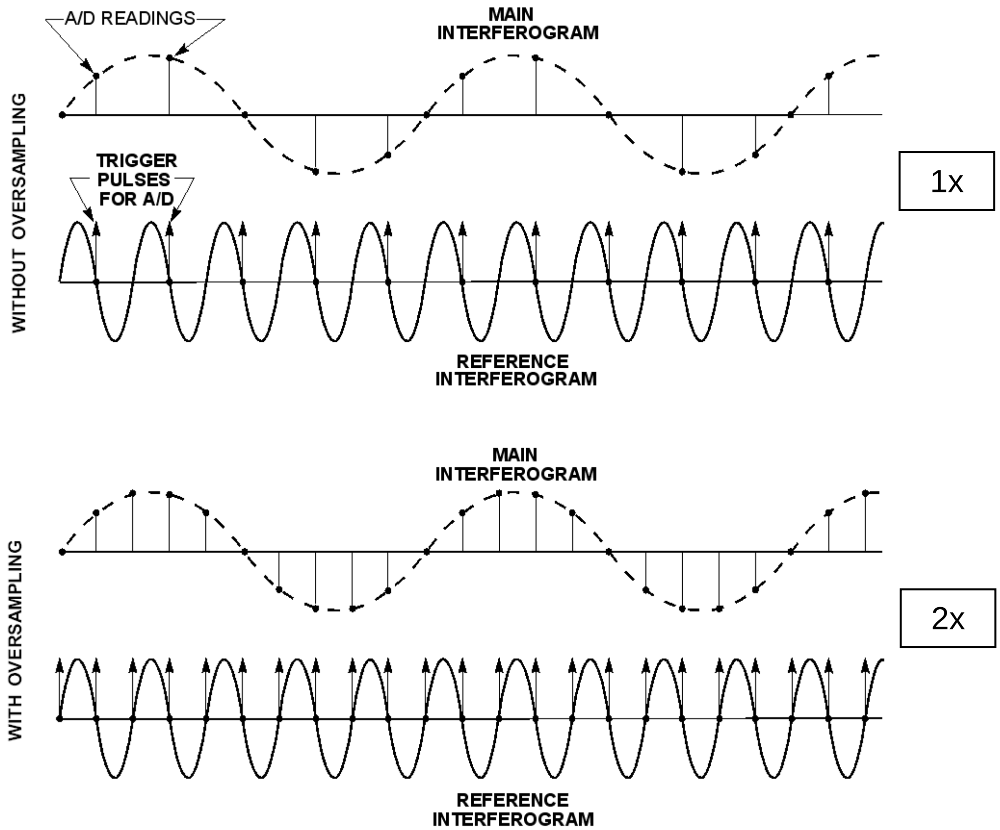

Figure 96: With oversampling, positive and negative zero crossings are used

There is a fundamental rule of information theory called the Nyquist theorem, which can be paraphrased to state that a sinusoid can be restored exactly from its discrete representation if it has been sampled at a frequency at least twice as high as its own frequency. If we apply this rule to the formula (Equation 3) we find immediately that since the minimum value of (f_r/f_i) is 2, so the minimum value of λ_i is twice the wavelength of the reference laser:

$$\lambda_{min} = 633 \text{ nm}*2 = 1.266 \text{ µm}$$

With oversampling, the reference laser wavelength is effectively halved. So in this case:

$$\lambda_{min} = (633\text{nm}/2)*2 = 633 \text{ nm}$$

In practice, the FFT math runs into difficulties close to the theoretical limit. That is why we say 1.4 µm is the limiting wavelength without oversampling, and 700 nm is the limiting wavelength with 4x oversampling.

It is possible to sample more or less frequently. Higher frequency sampling allows you to measure to lower wavelengths. Problems arise because alignment and motion fidelity become more critical, and the number of interferogram points require higher computational speed and more storage. Lower frequency sampling, i.e. sampling at every kth cycle of the reference interferogram instead of every cycle was more popular when memory and computational speed were a problem, since if appropriate anti-aliasing steps are taken, undersampling can be regarded as data compression.

20.2 Relationship between Resolution and Divergence

The FT-IR principle of operation is very different from typical dispersive instruments. Many aspects of this relatively new approach are counter intuitive to those of us accustomed to dispersive techniques, starting of course with the wavenumber units that go the wrong way.

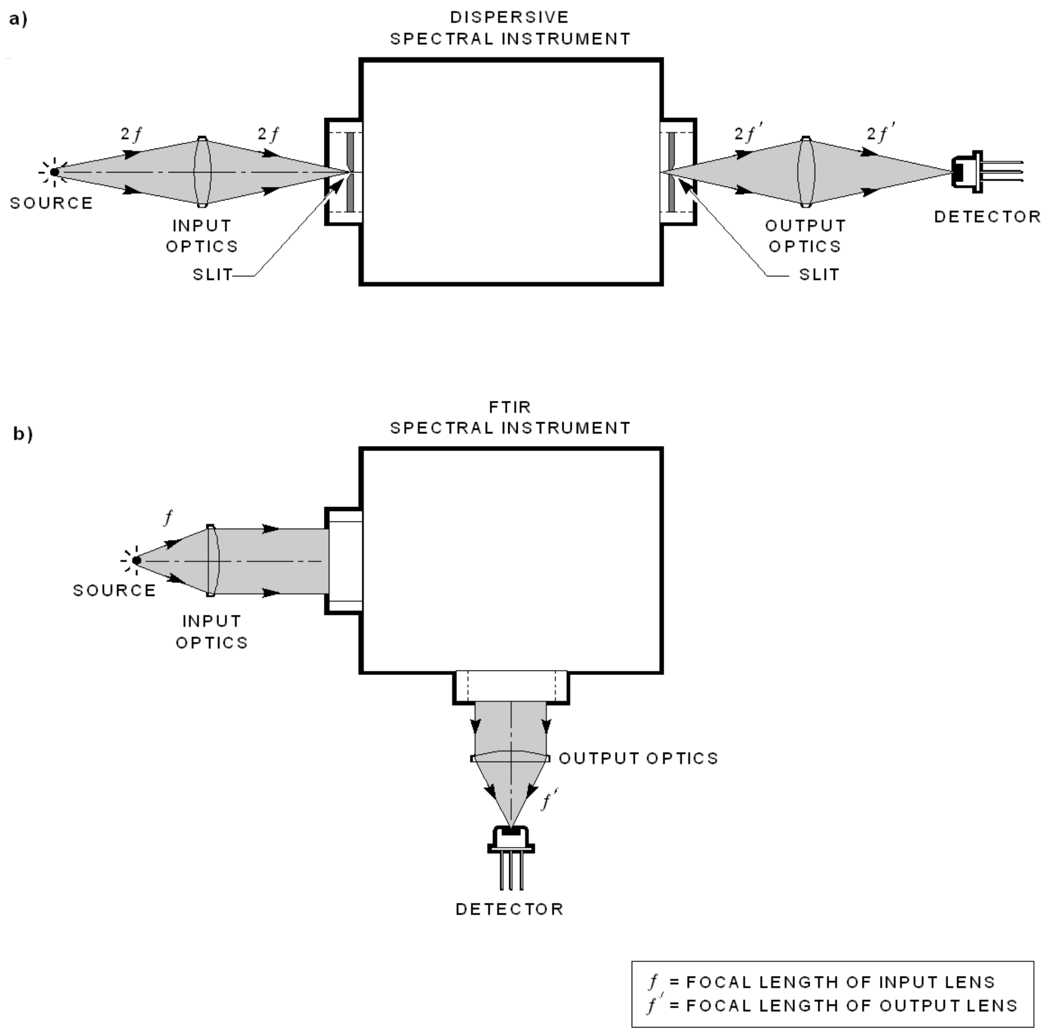

Figure 97: Typical optical layout of external optics relative to a dispersive monochromator

Figure 97-a shows a typical optical layout of external optics relative to a dispersive monochromator. Figure 97-b shows the same for an FT-IR spectrometer. The main optical feature of the FT-IR is that there are no focusing elements inside the instrument; it works with parallel beams.

Dispersive instruments from the input slit to an output slit are self-contained in the sense that major spectral characteristics do not depend very much on how you illuminate the input slit and how you collect the light after the output slit. Manipulating the light with external optics just gains or loses you sensitivity and adds or reduces stray light and aberrations.

This is not the case with FT-IRs. External optics are as important for proper functioning of the instrument as its internal parts. Figure 98 shows in a bigger scale a simplified scanning Michelson interferometer together with a source and a detector. Suppose first that the source is a (monochromatic) point source and therefore the beam entering the interferometer (rays 1 - 1') is perfectly parallel. Exiting the interferometer it will be focused into a point on the detector surface. With motion of the scanning mirror the detector will register an interferogram. A sequence of constructive and destructive interactions between two portions of the beam in the interferometer. The further the scanning mirror is traveling, the longer the interferogram, and the higher the spectral resolution that can be achieved.

In real life, point sources as well as purely parallel beams, do not exist. A finite size source produces a fan of parallel beams inside the interferometer. A marginal beam, 2 - 2', of this fan is shown in Figure 98.

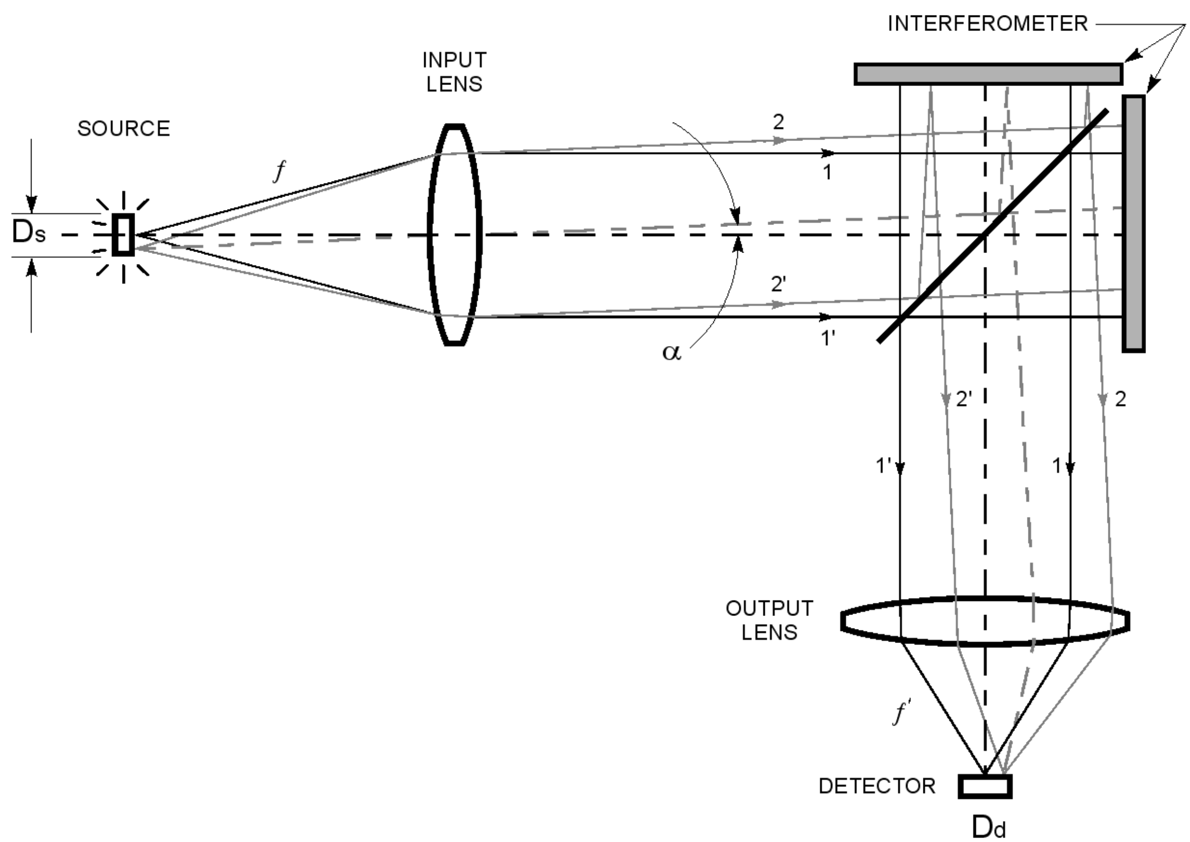

Figure 98: A finite source produces a fan of parallel beams inside an interferometer.

This beam will be focused at some distance from the center of the detector. To be exact it will be focused into a ring if the source has a round shape. Now the simple picture we had before becomes much more complex, since interference conditions will be different for the beams 1-1' and 2 - 2'.

At the zero optical path difference (ZOPD) both beams 1-1' and 2-2' are at constructive interference conditions and the whole detector will sense a high level of intensity. But while the scanning mirror moves away from the ZOPD position, the next condition of constructive interference will happen sooner for beam 2-2' than for beam 1-1'. As a result of that, different parts of the detector will see different phases of the interference pattern: a maximum in the center will be surrounded by a ring of minimum intensity, then a ring at maximum intensity again, etc.

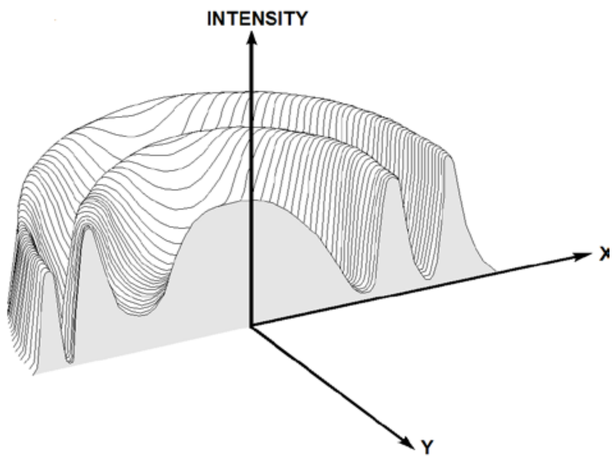

Figure 99: Interference pattern

The farther the scanning mirror moves, the tighter this ring pattern becomes. So the detector will see some average level of the intensity and the distinct interference picture recorded for the collimated input will be smeared. To get it back, we need to have just one fringe across the detector, as in Figure 100, when the ring pattern is the tightest, in other words when the OPD has is at its maximum value.

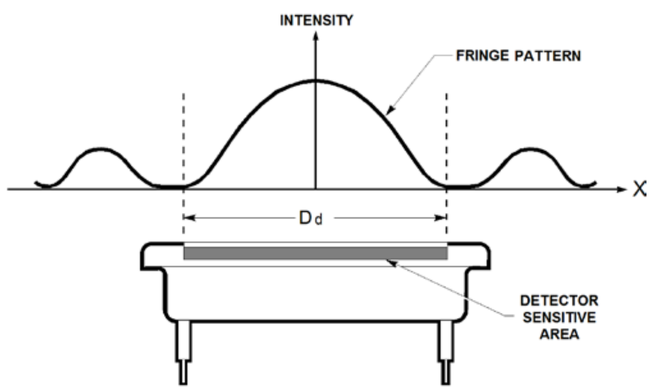

Figure 100: Intensity distribution at the detector

As we see from this simple consideration, an optimal functioning of the FT-IR requires certain restrictions on sizes of the detector and source, maximum angle of the fan of rays, maximum length of scan, spectral resolution and range of wavelengths. Since most of these parameters are related to each other, it would be practical to write one simple formula and then derive all other restrictions from it. The following formula ties together the highest wave number α_{max} that is to be observed, spectral resolution $\Delta\alpha$ and maximum divergence angle (half angle α_{max} in radians) that can be tolerated inside the interferometer:

$$\alpha_{max} = (\Delta\sigma/\sigma_{max})$$

Equation 4

For example if we wish to measure with 1 wavenumber resolution at 6667 wavenumbers, (1.5 μm), then the half angle divergence of the beam inside the interferometer must be less than 12.2 milliradians. Input and output optics, as we see from Figure 99 are the components that provide an FT-IR with the required divergence angle.

20.3 External FT-IR Optics: General Considerations

The task of external FT-IR optics, as we saw in the previous section, is not only to collect and collimate light but also to provide a certain acceptance angle in the system according to the resolution formula. To be able to perform calculations for FT-IR auxiliary optics we will need first to revisit some basic optical ideas. This touches on one of the most fundamental but neglected laws of radiation that affects the design of optical systems that Oriel Instruments offers.

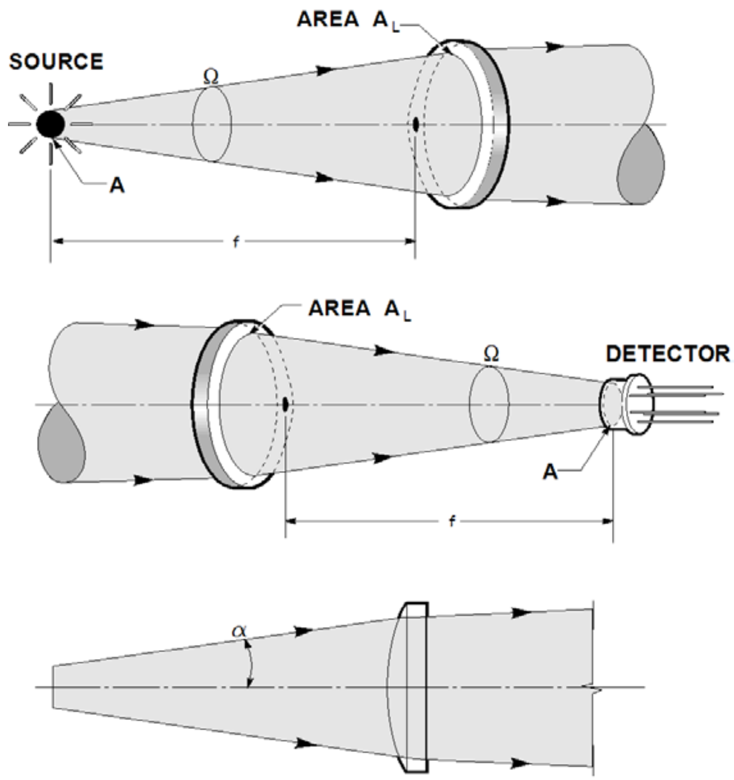

Figure 101: Solid angles and conventional angles.

Consider light collected by a lens onto a focal spot or emitted by a source placed in the focal plane of a lens. The solid angle of the cone of rays collected from the source, or alternately directed onto the focal spot, is given by:

$$\Omega = A_L / f^2 \text{ sr}$$

Equation 5

where both f and A_L are expressed in the same units, e.g. m, m^2, or mm, mm^2 and:
A_L = the area of the collecting/focusing lens
f = lens focal length

$$\Omega = \pi / (4F^2/\#) \text{ sr}$$

Equation 6

We can use F/# instead of focal length in Equation 6. So an F/4 lens collects a solid 0.05 sr, while an F/1 lens collects 0.79 sr.

This collection concept leads to many problems when we talk about our F/1 vs. F/1.5 etc. condensers. If a point source, such as a small arc, emits isotropically, then the simple geometrical comparison would give us the ability to compare by calculation. Our sources are not isotropic emitters, even the arcs, are not point sources, and one can immediately see that the flat tungsten filaments are Lambertian rather than isotropic emitters. We have made measurements for arcs and base our conversion factors on these. We also oversimplify in not providing measured factors for each arc and for QTH lamps, and we also neglect to give the exact F/# for our condensers.

In the more familiar two-dimensional picture we use the divergence angle related to the solid angle by:

$$\alpha^2=\Omega/\pi \text{ radians}$$

Equation 7

The product of solid angle and area of an image at a plane where the solid angle originates is called by various names, optical extent, geometrical extent or étendue. (Often, the term throughput is used instead of étendue and I am sure we do so somewhere in this material. The latter refers only to the “spatial” properties of the instrument/beam. Throughput includes this and the reflectance and transmittance of the optics of the system). Étendue determines the "radiation capacity" of an optical system. The fundamental law of optics, mentioned above states that any optical system can be characterized by an optical extent/étendue/ throughput which stays constant through all optical transformations:

$$G = A*\Omega= \text{const.}$$

Equation 8

Note that in Figure 99, the area A is that of the source or “detector”.

The relevance of this is that every optical system has something that sets or limits the value of G. Knowing what part that is and improving it as best as possible is fruitful. Working to increase the G value for another part of the system is a waste of time, but a very common waste of time.

In what follows, we consider the étendue of the MIR8035™. It’s important to not confuse the resolution restrictions on étendue, the output or detector étendue, and the source side étendue. In general we like to start by knowing what the largest étendue we can tolerate to get the resolution we need. If the étendue of the instrument, including source and detector, is larger than this, then we have to lower the system value to ensure we get the resolution.

Let's determine the resolution limit on étendue for the MIR8035™. We know that it has an aperture of 1.25 inches (31.75 mm). We can also find a maximum allowed divergence angle of a beam propagating through it according to a maximum wave number in a spectrum and required resolution, formula from Equation 4. From this we can find the maximum solid angle of the fan of rays making use of Equation 7 ($\Omega_{max} =\pi\alpha^2_{max}$).

Thus we will find the étendue of the interferometer:

$$G_{intfr} = 2.5*10^{3}*[\Delta\sigma]/[\sigma_{max}]\ mm^{2}\ rad^{2}$$

$$G_{intfr} = \pi*(31.75)^{2}/(4\ \sigma_{max})$$

and using:

$$(4)\ \alpha_{max}^{2}=\Delta\sigma/\sigma_{max}$$

Equation 9

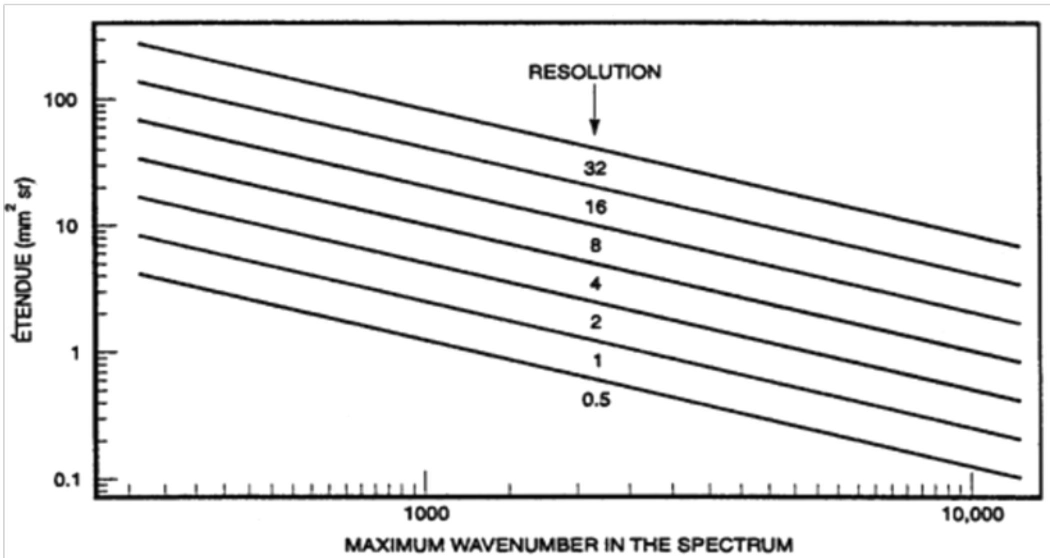

Figure 102: MIR8035™ Étendue vs. Maximum Wavenumber, at different resolutions

Example:

The shortest wavelength we want to observe in the spectrum is 2 microns, which is equivalent to 5000 cm^{-1}. The desired spectral resolution is 4 cm^{-1}.

From Equation 9 we get:

$$G_{intrf} = 2\ mm^{2}rad^{2}$$
$$= 2\ mm^{2}sr$$

Equation 10

The following sections illustrate the need to carefully choose and arrange auxiliary optics for an interferometer. If the desired resolution cannot be achieved, it is most likely due to poor alignment, wrongly chosen focal length of optics, etc.

20.4 External FT-IR Optics: Detector Optics

Now let us consider auxiliary optics; first, on the detector side. Suppose that the allowed acceptance angle is filled fully with light. Continuing the conditions cited in the example above, we want to collect this light and squeeze it onto the smallest possible detector, since typically smaller detectors have better noise characteristics. To do this we will take a very fast lens with F/# = 1.

Then according to Equation 6 the solid angle at the focal spot will be:

$$\Omega_d = 0.79 \text{ sr}$$

Equation 11

At the same time the light we are dealing with is propagating through the interferometer, and therefore Equation 8 is applicable to it:

$$G_{intrf} = G_d = \Omega_d * A,$$

Equation 12

Where A equals to area of the focal spot.

From Equation 10 and Equation 12 we get: A= 2/0.79 = 2.56 mm2

If we want to intercept all the light we have to use a detector with the same area, $A=A_{d,}$ or in other words, having diameter:

$$D_d = \sqrt{(4*2.56/\pi)} = 1.8 \text{ mm}$$

The highest resolution for the MIR8035™, 0.5 cm^{-1} corresponds to about a 0.6 mm detector diameter and G = 0.22 mm^2 rad^2 still considering σ_{max} = 5,000cm^{-1}. At the same time, working at the lowest resolution, that is 64 cm^{-1}, we could get away with as much étendue as 32 mm^2 rad^2. This means that at lower resolutions, we could potentially pump into the system a lot more radiation without impacting the resolution performance.

But if we've chosen a 0.6 mm diameter detector, we cannot actually use this radiation. What can we do in this situation? We do not have the luxury of using a different detector for each resolution. For general use, we can choose one detector, which corresponds to a reasonably high, but not necessarily the highest resolution. 4 cm^{-1} is a popular choice for this, because 4 cm^{-1} resolution is plenty for condensed phase work.

What if subsequently we need a higher resolution? There are a couple of ways to handle this eventuality. One way is to increase the focal length of the detector's fore optics. Longer focus means higher F/#, lower throughput and a higher allowed resolution. It means, of course, a radiation loss also.

Another way is to use an aperture to increase the F/#, by decreasing the effective source size, this reduces the spot size on the detector; in FT-IR jargon use a Jacquinot stop. This method will be further discussed in Section 20.5.

One needs to be careful in extending the model above. A question which is sometimes asked: what if we use a 0.5 mm diameter detector, which corresponds to 0.25 cm^{-1} resolution at 5000 cm^{-1}? Will we get this kind of resolution? The answer is no. The length of the scan of the moving mirror allows you to get 0.5 cm^{-1} at best. With proper optical arrangements you can approach this limit but you can never surpass it. The same is true for all other resolution settings of the interferometer.

20.5 External FT-IR Optics: Source Optics

Ideally, the source with its optics should present a beam with étendue equal to the required étendue of the interferometer. We have seen that the étendue of the instrument is limited by the desired resolution or detector size and optics. The source étendue is determined by the source size and the source optics, the product of the source area and the solid angle subtended by the input at the source center:

$$G_S = A_S \Omega_{input}$$

Usually, as the source has a larger diameter than the detector, using short focal length optics, it delivers a more divergent beam to the interferometer than is necessary for the given resolution. In this case the detector is the one which really sets the system étendue/spectral resolution limit. Nothing is gained by the "overfilling" of the input, and there is always the possibility that some of the wasted light will find its way to the detector and cause trouble, just as happens in a monochromator.

Of course in an open bench approach, source optics can be slower than detector optics when the source sizes are large. A 5 mm size IR emitter with F/# = 2.5 optics will have according to Equation 6 and **Equation 8** an étendue G_{input} = 3.25 mm^2rad^2, which is higher than we need for 4 cm^{-1} resolution in the example we are considering.

There exists an arrangement (see Figure 103), which allows you to have a variable throughput (and therefore variable resolution) in the system without changing focal lengths of lenses or size of a detector. Lens 1 projects the source in plane 2 where a variable aperture (usually called a Jacquinot stop) is placed. This apertured radiation is collected and collimated by lens 3. This arrangement is also particularly important for radiometry applications, where different size sources are measured and compared with a calibrated source that may be significantly different in size.

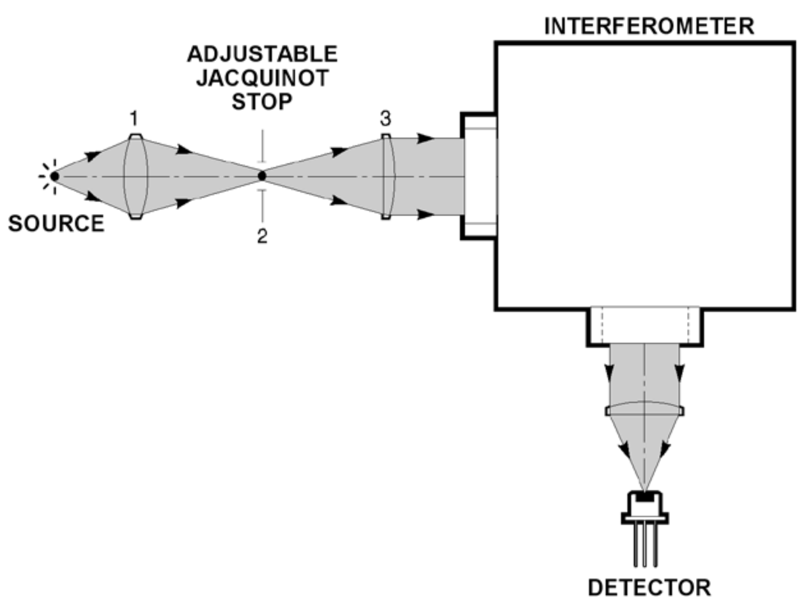

Figure 103: Interferometer with Jacquinot Stop

To be specific, let's assume that the étendue of the detector unit is 2 mm^2 *rad^2 which determines the required resolution 4 cm^{-1}; F/# of lens 3 is 2.5 . At the interferometer settings for the resolutions 4, 8, 16, 32, 64 cm^{-1}, the detector will represent the limiting factor and these resolutions should be achieved. When the interferometer is set for higher resolution, 2, 1, or 0.5 cm^{-1}, we will still get no better spectral resolution than 4 cm^{-1}, the best achievable with the divergence or convergence we have.

But we can make use of the Jacquinot stop. Closing the aperture reduces the divergence, and unfortunately also the signal level. The attainable resolution is improved, and if we have enough signal we can attain the resolution limit set by the fundamental rule of scan length.

We have talked about the étendue of the MIR8035™, and said that it differs from the throughput because of the performance of the optics. The étendue takes into account just the geometrical factor. Poor reflectance, say, from the corner cubes, will reduce the throughput, but not affect the étendue. Measurements on the MIR8035™ show the throughput is around 0.15 to 0.2 times the étendue. Sometimes the multiplier is called efficiency and designated $\xi(\sigma)$ since it depends on the wavenumber.

The real throughput of a spectral instrument (including an FT-IR) relates to the étendue through:

$$Q = G^*\xi(\sigma),$$

Equation 13

where $\xi(\sigma)$ is dimensionless.

For an FT-IR, a typical number for the maximum value of $\xi(\sigma)$ is 0.2. The spectral dependence of $\xi(\sigma)$ is determined mainly by the efficiency and transmittance of the beam splitter. It stays relatively flat through most of the spectral design range and quickly rolls to zero at the extremes of the spectral range where either the beam splitter's coating or substrate become absorptive.

It will be useful for comparison to estimate an étendue and throughput of a dispersive instrument with the same resolving power $R = \sigma/\Delta\sigma = 5000/4 = 1250$ as in the example above. For a grating instrument the calculation is complicated by the slit geometry, resolution dimension issue i.e. we don't have the friendly circular geometry that applies to the FT-IR. Here we just give a result, we will expand on the comparison later.

Operating at 2000 nm with a 1250 resolving power gives a resolution of 1.6 nm. With a 300 l/mm grating in the Newport 77250 Monochromator for example, the slit widths are set to 62.5 µm. The slit height is somewhat arbitrary, but as our detectors are typically 3 mm in that dimension, and as the best we can do is refocus the output with an F/1 optic on the detector from the F/4 instrument, we choose 12 mm for the slit height.

The étendue for the monochromator is given approximately by the product of the slit area and the acceptance angle. As the grating turns from normal incidence, this will decrease, but here we are approximating. The acceptance angle is 0.057 sr and the area is 12* 0.05 mm^2.

Therefore:

$$G_{mono} = 0.034 \text{ mm}^2\text{sr}$$

This compares with 2 mm^2 sr for the FT-IR, so geometrically, the FT-IR has 60 times the throughput of the monochromator. The efficiency of the monochromator may be two to three times that of the FT-IR near blaze, leaving the FT-IR advantage at ~20-30.

Consider a small source, area $A_{s,}$ with spectral radiance of I_σ, at σ and let=s assume the source is an isotropic emitter. The total power is then $4\pi A_s I_\sigma$ at σ watts per wavenumber. The spectral power collected at the input is:

$$L_\sigma = I_\sigma A_s \Omega_{input} = I_\sigma G_{input} \text{ W Hz}^{-1}$$

For a matched system, with detector étendue equal to that of the input, the detected power will be given by:

$$B_d = \xi(\sigma) I_\sigma G \text{ W Hz}^{-1}$$

where:

$$G = G_{input} = G_{output}$$

FT-IR instruments use basically two methods of scanning. In one of these the path length for the two beams is equal when the scanning mirror is in the middle of its mechanical scan range. The ZOPD occurs in the center of the scan.

The interferograms are termed double sided or single sided, accordingly.

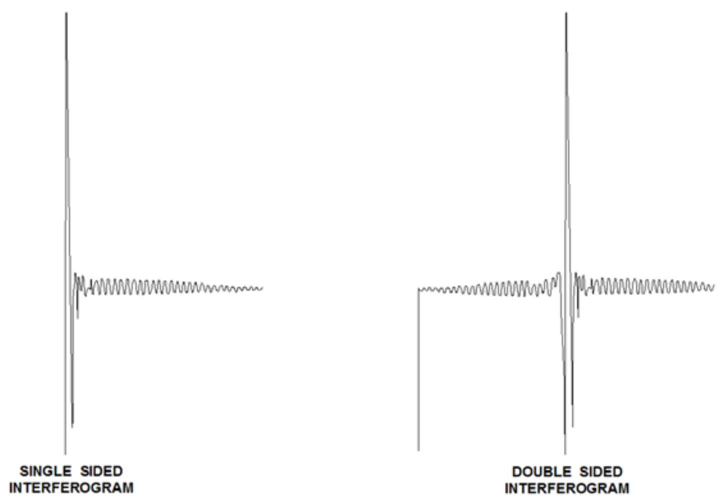

Figure 104: Single and double sided interferograms

The ideal double sided interferogram is perfectly symmetrical, so the full information is available from either side, and one side appears redundant. Actual interferograms have some degree of asymmetry. This is due to such factors as beam divergence over the scan path, dispersion of the beam splitter material, distortion in the detector and signal circuitry, etc. that gives rise to phase shifts between the ideally equi-phased sinusoids. To get the real spectrum from the interferogram requires some phase correction for the interferogram. This is done by using a phase correction algorithm and the one used in the MIR8035™ is the popular Mertz phase correction algorithm. The MIR8035™ uses double sided interferograms, relying on the retro-reflectors and robust scan construction.

20.6 External FT-IR Optics: Off-Axis Parabolic Reflectors

Practically all FT-IR instruments use off-axis parabolic reflectors for collimating and focusing light external to the interferometer. An off-axis parabolic reflector is a segment of a full parabolic reflector. These gold-coated mirrors are very broadband, from 0.7 to 10 microns they reflect more than 98%, and it stays in this range up to 25 microns. Bear in mind that for wavelengths shorter than 0.6 micron, gold is a bad reflector; its reflectivity drops abruptly to less than 40%. An important feature of reflectors in general is that they do not have any dispersion; there is no chromatic aberration so the focal spot stays at the same place for any wavelength. They do have monochromatic aberrations.

Parabolic reflectors are devices ideally suited for collimating light from small sources and conversely for tightly focusing collimated beams of radiation. They are however limited to this purpose. They cannot be used for imaging. Spherical mirrors, on the other hand, can be used for imaging (by "imaging" we mean transferring some source placed at a finite distance from the mirror into an image positioned also at a finite distance from the mirror).

Light from a point source placed in a focus of a full parabolic reflector Figure 105 will be transformed after reflection into an ideally parallel beam. Accordingly, a parallel beam will be focused into a tiny focal spot. This is true for any section of the parabola. So, an off-axis section of the parabolic reflector can be cut out for convenience, as illustrated in Figure 106.

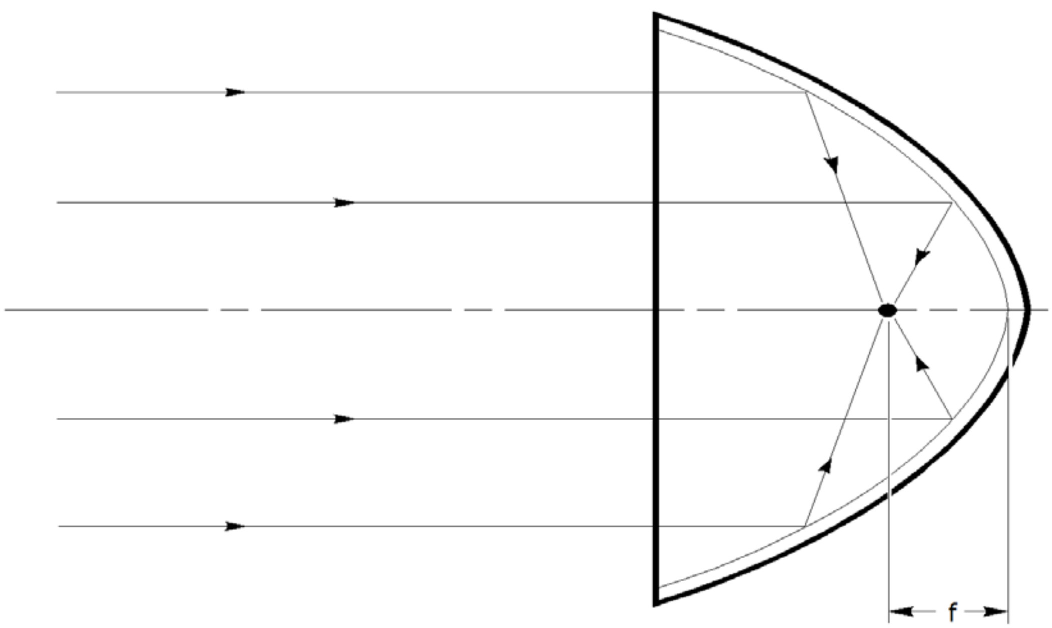

Figure 105: Light from a point source placed at the focus of a parabolic reflector

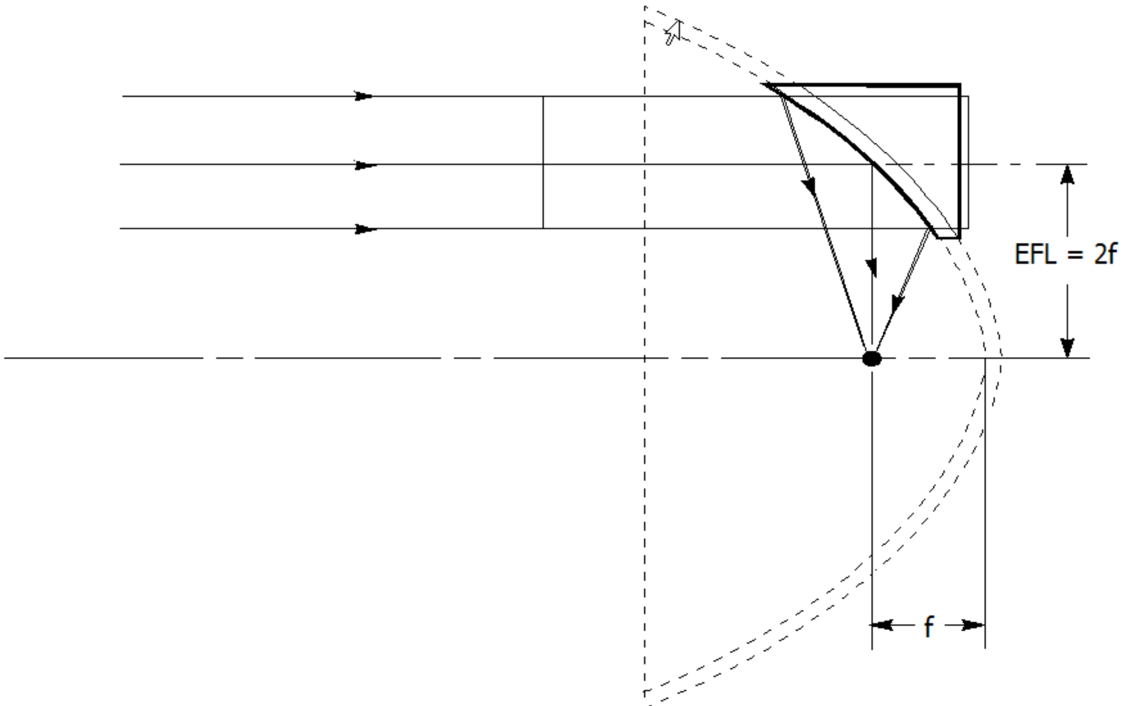

Figure 106: Section of an off-axis parabolic reflector

The arrangement shown in Figure 106 is described as a 90° off-axis reflector since the ray striking the center of the aperture and parallel to the main axis turns exactly at 90 degrees and comes into the focal point. The distance from the point on the surface of the parabola at the center of the aperture to the focal point is called effective focal length EFL and it is exactly two times the focal length of the parabola: EFL = 2f.

F-numbers of off-axis parabolic mirrors can reach very low values: F#/1 or even less is practical. If not a point but a finite size source is placed in the focal point of the parabola, the reflected beam will not be ideally parallel any more. It will have some angular divergence according to the angular size of the source. Additionally, it will suffer from all kinds of aberrations. Accordingly, a non-parallel incoming beam will be focused into, not a spot, but into a certain size blur.

It is important to analyze how the angular divergence of a beam turns into a blur spot in a parabola focus. We created the optical schematic of the MIR8035™ with an F/1 parabolic mirror at the output. The effective focal length of the mirror was 20 mm. We traced rays with different divergence through the system and watched for the focal spot size. Figure 107 shows a graph of the diameter of the focal spot vs. angular divergence of the beam propagating through the interferometer.

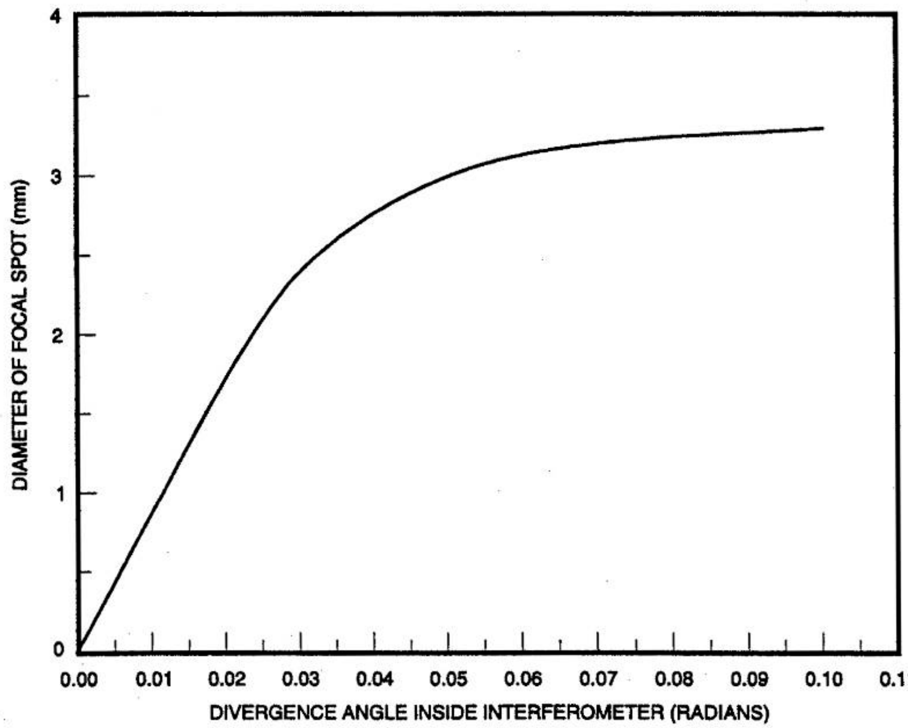

Figure 107: Diameter of Focal Spot vs. Angular Divergence.

The limit on divergence angle in the interferometer we found from formula Equation 4, at the smallest possible $\Delta\sigma$, which is 0.5 cm^{-1} and the highest possible σ, which is 14,000 cm^{-1}, is 0.006 rad. The graph shows that the diameter of the focal spot, which corresponds to this value, is about 0.5 mm. It is interesting to mention that the rough estimate, of the same value made with formulas Equation 6 Equation 7 and Equation 13 gives a value of 0.4 mm.

With increasing divergence of the beam, the diameter of the focal spot also increases, as we see, but it has some limit between 1.5 and 2 mm. The reason for this is that the interferometer itself is blocking high angle rays and they simply do not reach the parabolic reflector. The maximum value of angle of rays that can get through the interferometer is 0.06 to 0.07 rad. This is exactly the region where the curve in Figure 107 starts to flatten out.

Figure 108 shows the energy distribution in the focal plane of the off-axis reflector for beams of different divergence. This shows the increasing impact of aberrations as the field of view of the parabola is increased.

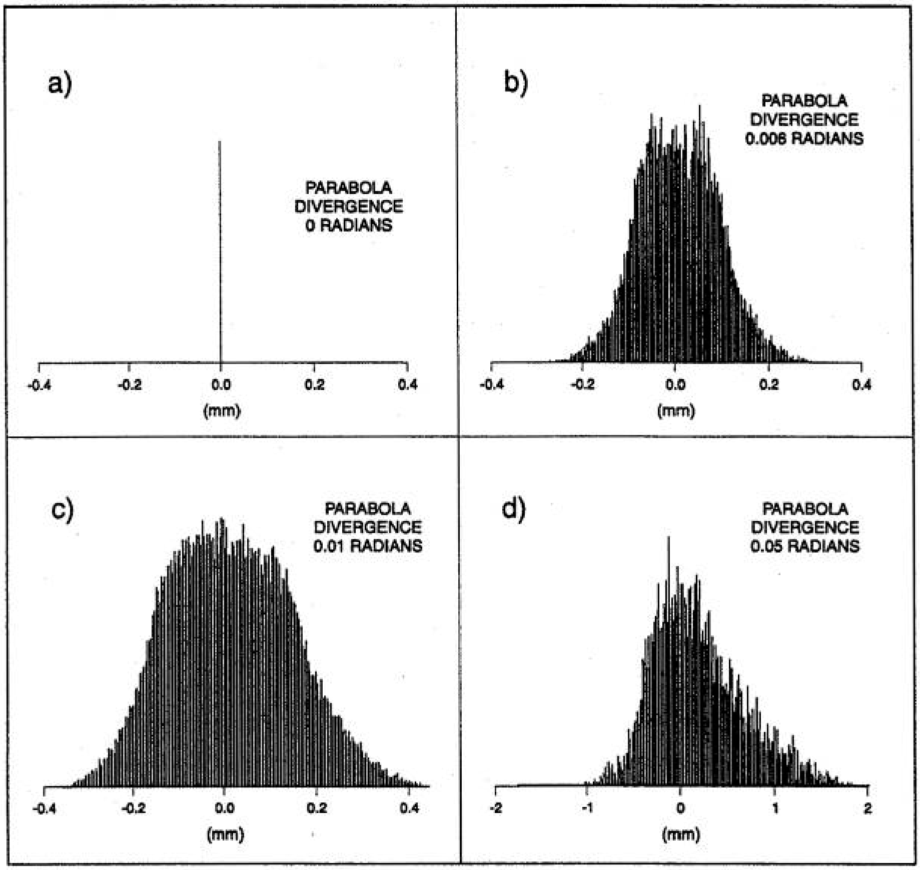

Figure 108: Energy distribution in the focal plane of an off-axis reflector.

Despite universality and wide usage of off-axis parabolic reflectors in FT-IR spectroscopy, they have certain disadvantages. Alignment is fairly difficult. Each reflectance turns the beam through 90 degrees, and this may make the system bulky. At low F/#, i.e. large fields of view (high étendue), they suffer from significant aberrations.

20.7 External FT-IR Optics: Lenses

In many applications, especially in the Near IR, lenses could be a good choice. Figure 109 shows the energy distribution in the focal spot of a CaF_2 lens having about the same focal length and F/# as the parabolic mirror considered in Figure 108.

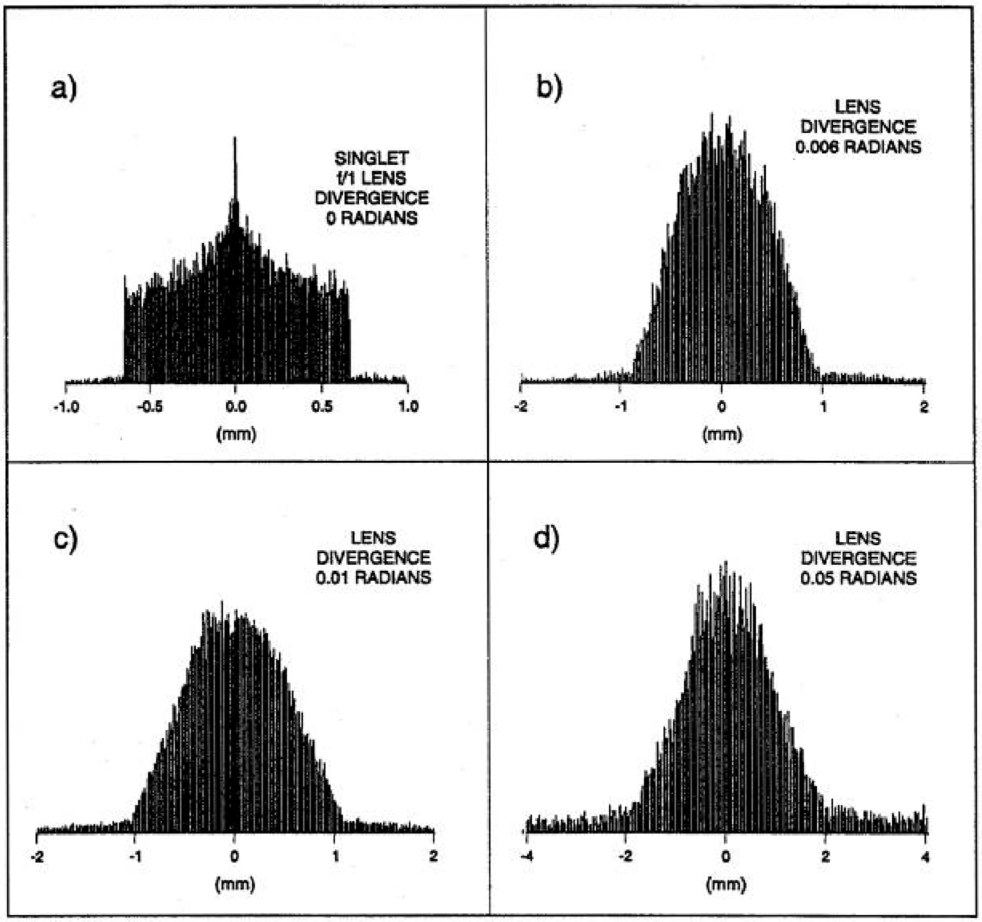

Figure 109: Energy distribution in the focal plane of CaF_2 lens

What is there to worry about when working with lenses? First: material; we recommend the use of CaF_2 lenses in the whole range where the CaF_2 beam splitter is applicable. In the very Near IR up to 3 microns, fused silica lenses are fine, though the water absorption bands may cause some loss. They are somewhat cheaper than CaF_2 lenses.

A wide variety of materials are available for the Mid IR. You've usually got a choice among performance, expense, durability, birefringence, etc. The hygroscopic nature of some materials can be a big problem. NaCl and KBr windows are two such popular materials, Some materials are transparent in the visible and others not; this can be a plus if you are trying to align in the visible, or a negative when you would prefer the material to act as a filter.

Basically, the only rugged and transparent material which is used for manufacturing lenses is ZnSe. It has, however, a very high index of refraction that pushes reflectance losses to relatively high levels: up to

30%, and it is considered expensive. You can coat it, at further expense, and reduction of the spectral range. You can find transmittance curves of different IR materials in Newport's catalog and website.

A second issue is dispersion of the lens material. Lenses are definitely good for short wavelength range applications. For example, the sensitivity range of an InGaAs detector is very short: from 800 to 1700 nm. Using a lens should not pose a major problem, though we do see some dispersion in our labs with fused silica lenses over this range; i.e. you can axially move the lens to optimize the long wavelength or short wavelength signal.

For a wider wavelength range you should position the detector at the shortest focal length position, in other words, in the position of minimum spot size for the shortest wavelength. Then, you can be safe for longer wavelengths.

21 Appendix B: Glossary of Terms

100% Line: Calculated by ratioing two background spectra taken under identical conditions. Ideally, the result is a flat line at 100% transmittance.

Absorbance: Units used to measure the amount of IR radiation absorbed by a sample. Absorbance is commonly used as the Y axis units in IR spectra. Absorbance is defined by Beer's Law, and is linearly proportional to concentration.

Aliasing: If frequencies above the Nyquist Frequency are not filtered out, energy in these will appear as spectral artifacts below the Nyquist Frequency. Optical and electronic anti-aliasing can be used to prevent this. Sometimes the higher frequencies are said to be "folded" back so the term "folding" is used.

Angular Divergence: The spreading out of an infrared beam as it travels through the FT-IR. Angular divergence contributes to noise in high resolution spectra, and can be a limit to achievable resolution.

Apodization Functions: Functions used to multiply an interferogram to reduce the amount of side lobes in a spectrum. Different types of apodization functions include boxcar, triangle, Beer-Norton, Hanning, and Bessel. The use of apodization functions unavoidably reduces the resolution of a spectrum.

ATR: Abbreviation which stands for Attenuated Total Reflectance, a reflectance sampling technique. In ATR, infrared radiation impinges on a prism of infrared transparent material of high refractive index. The total internal reflectance based design assures that the light reflects off the surface of the crystal at least once before leaving it. The infrared radiation sets up an evanescent wave which penetrates a small distance above and below the crystal surface. Samples brought into contact with the surface will absorb the evanescent wave giving rise to an infrared spectrum. This sampling technique is useful for liquids, polymer films, and semisolids.

Background Spectrum: A single beam spectrum acquired with no sample in the infrared beam. The purpose of a background spectrum is to measure the contribution of the instrument and environment to the spectrum. These effects are removed from a sample spectrum by ratioing the sample single beam spectrum to the background spectrum.

Baseline Correction: A spectral manipulation technique used to correct spectra with sloped or varying baselines. The user must draw a function parallel to the baseline, then this function is subtracted from the spectrum.

Boxcar Truncation: With no apodization, all points in an interferogram are given equal weight, up to the edges of the interferogram. If the resolution is less than the smallest line width in the spectrum, oscillations appear on the baseline on both sides of the peaks.

Centerburst: The sharp, intense part of an interferogram. The size of the centerburst is directly proportional to the amount of infrared radiation striking the detector.

Coadding: The process of adding interferograms together to achieve an improvement in signal-to-noise ratio.

Collimation: The ideal input beam is a cylinder of light. No beam of finite dimensions can be perfectly collimated; at best there is a diffraction limit. In practice the input beam is a cone that is determined by the source size or aperture used. The degree of collimation can affect the S/N and the resolution

Constructive Interference: A phenomenon that occurs when two waves occupy the same space and are in phase with each other. Since the amplitudes of waves are additive, the two waves will add together to give a resultant wave which is more intense than either of the individual waves.

Destructive Interference: A phenomenon that occurs when two waves occupy the same space. Since the amplitudes of waves are additive, if the two waves are out of phase with each other, the resultant wave will be less intense than either of the individual waves.

Diffuse Reflectance: The phenomenon that takes place when infrared radiation reflects off a rough surface. The light is transmitted, absorbed, scattered, and reflected by the surface. The light approaches the surface from one direction, but the diffusely reflected light leaves the surface in all directions. A reflectance sampling technique known as DRIFTS is based on this phenomenon.

Dispersive Instruments: Infrared spectrometers that use a grating or prism to disperse infrared radiation into its component wavenumbers before detecting the radiation. This type of instrument was dominant before the development of FT-IR.

DTGS: Deuterated tri-glycine sulfate pyroelectric detectors are the most common detectors used in FT-IR instruments. They are chosen for their ease of use, good sensitivity, wide spectral responsivity and excellent linearity

Duplicate Range: For an interferogram, it is the ratio of the large centerburst signal at ZOPD to the smallest recorded signal (which must be greater than the noise for any benefit from signal averaging). The A/D used must have sufficient precision to measure the entire range as any clipping or distortion of the largest signal affects the whole spectrum.

Dynamic Range: For an interferogram, it is the ratio of the large centerburst signal at ZOPD to the smallest recorded signal (which must be greater than the noise for any benefit from signal averaging). The A/D used must have sufficient precision to measure the entire range as any clipping or distortion of the largest signal affects the whole spectrum.

Felgett (multiplex) Advantage: An advantage of FT-IR instrument compared to scanning/single channel dispersive instruments. It is based on the fact that in an FT-IR all the wavenumbers of light are detected at once.

Fourier Transform: Calculation performed on an interferogram to turn it into an infrared spectrum.

Interferogram: A plot of infrared detector response versus optical path difference. The fundamental measurement obtained by an FT-IR is an interferogram. Interferograms are Fourier transformed to give infrared spectra.

Jacquinot or J Stop: An aperture placed in the beam to restrict the divergence to the maximum compatible with the selected resolution. When choosing lower resolution you can improve the S/N by opening the stop. Note that in many instances there is no physically separate stop but there will be some aperture, be it the source size, or the detector active area, that acts as the system J stop.

Jacquinot Advantage: This is the throughput advantage of FT-IRs over traditional spectrometers that require a slit aperture. The advantage varies as wavenumber and depends on resolution (because of slit width changes). In practice, any advantage will also depend on source dimensions.

Mirror Displacement: The distance that the mirror in an interferometer has moved from zero path difference.

Normalized: The process of dividing all the absorbance values in a spectrum by the largest absorbance value. This resets the Y axis scale from 0 to 1.

Nyquist Frequency: A term widely used in information theory, but here applies to the highest frequency, shortest wavelength, that can be identified in an interferogram. It is the one for which there are exactly two points per cycle. The contribution of any higher frequency, signal or noise, can be represented by some lower frequency and so will appear aliased or folded into the spectrum.

Optical Distance: Physical distance multiplied by the index of refraction of the medium.

Optical Path Difference: The difference in optical distance that two light beams travel in an interferometer.

Phase Correction: A software procedure to compensate for not taking a data point exactly at ZOPD, and for frequency dependent variations caused by the beam splitter and signal amplification. The Mertz and Forman corrections are both used with the Mertz applied to double sided interferograms; this is considered in the most accurate approach.

Resolution: A measure of how well an IR spectrometer can distinguish spectral features that are close together. For instance, if two features are 4 cm^{-1} apart and can be discerned easily, the spectrum is said to be at least 4 cm^{-1} resolution. Resolution in an FT-IR is mainly determined by the optical path difference.

Sidelobes: Spectral features that appear to the sides of an absorbance band as undulations in the baseline. Sidelobes are caused by having to truncate an interferogram, as a result of finite scan distance, and can be removed from a spectrum by multiplying the spectrum's interferogram by an apodization function.

Single Beam Spectrum: The spectrum that is obtained after Fourier transforming an interferogram. Single beam spectra contain features due to the instrument, the environment, and the sample.

Smoothing: A spectral manipulation technique used to reduce the amount of noise in a spectrum. It works by calculating the average absorbance (or transmittance) of a group of data points called the "smoothing window," and plotting the average absorbance (or transmittance) versus wavenumber. The size of the smoothing window determines the number of data points to use in the average, and hence the amount of smoothing.

Spectral Subtraction: A spectral manipulation technique where the absorbances of a reference spectrum are subtracted from the absorbances of a sample spectrum. The idea is to remove the bands due to the reference material from the sample spectrum. This is done by simply calculating the difference in absorbance between the two spectra, then plotting this difference versus wavenumber. The reference spectrum is often multiplied by a subtraction factor so that the reference material bands subtract out properly.

Transmission Sampling: A sampling method where the infrared beam passes through the sample before it is detected. Samples are typically diluted or flattened to adjust the absorbance values to a measurable range.

Wavelength: Distance between adjacent crests or troughs of a light wave.

Wavenumber: 1/wavelength, the units of wavenumbers are cm^{-1}, and are most commonly used as the X axis unit in infrared spectra.

1 µm = 1,000 nm = 10,000 cm-1
5 µm = 5,000 nm = 2,000 cm-1

Zero Path Difference, or Zero Optical Path Difference: The mirror displacement at which the optical path difference for the two beams in an interferometer is zero. At ZPD, ZOPD, the detector signal is often very large, the centerburst.

22 WARRANTY AND SERVICE

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Product serial number and date of manufacture (located on the product label).
Description of the problem.

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What was the state of the system right before the problem?
Had this problem occurred before? If so, when and how frequently?
Can the system continue to operate with this problem, or is it non-operational?
Were there any differences in the application or environment before the problem occurred?

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